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STUDY OF DEEPWATER PORT OIL TRANSFER CONTROL SYSTEMS

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16. Abstract

This report deals with the description, reliability and rating of oil transfer control systems in Deepwater Ports.

A typical oil transfer control system is hierarchically defined along with equipment description and purpose, reliability, spill risk, effects of failure and alternative procedures. A numerical rating system is presented which enables the design reviewer to compare a proposed control system with a benchmark system. Equipment Staging Diagram, Fault Trees and a Failure Mode and Effects Analysis are presented for the defined control system to aid in its analysis.

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2. Risk Analysis Methods for Deepwater Port Oil Transfer Systems - Report No. CG-D-69-76, June 1976.

3. Code of Federal Regulations, Title 46, Shipping, Subchapter J, Electrical Engineering.

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ABBREVIATIONS

AE	-	AIR ELIMINATOR
DPS	-	DIFFERENTIAL PRESSURE SWITCH
DS	-	DRIFT SWITCH
DWP	-	DEEPWATER PORT
EMC	-	ELECTRIC MAGNETIC CONTROL
DMG	-	EMERGENCY VALVE
EMF	-	ELECTROMOTIVE FORCE
ESD	-	EQUIPMENT STAGING DIAGRAM
FCV	-	FLOW CONTROL VALVE
FE	-	FLOW ELEMENT
FI	-	FLOW INDICATOR
FIG	-	FLOW INTEGRATER
FIR	-	FLOW INTEGRATING RECORDING
FMEA	-	FAILURE MODES AND EFFECTS ANALYSIS
FSD	-	FUNCTIONAL STAGING DIAGRAM
FT	-	FLOW TRANSMITTER
HL	-	HIGH LEVEL
HHL	-	HIGH HIGH LEVEL
HI	-	HIGH
HP	-	HIGH PRESSURE
IND	-	INDICATOR
LI	-	LEVEL INDICATOR
LL	-	LOW LEVEL
LLL	-	LOW LOW LEVEL
LP	-	LOW PRESSURE
LS	-	LEVEL SWITCH
LT	-	LEVEL TRANSMITTER
MBTF	-	MEAN BARRELS TO FAILURE
MOV	-	MOTOR OPERATED VALVE
OSD	-	OPERATIONAL SEQUENCE DIAGRAM
PC	-	PRESSURE CONTROLLER

PCV	-	PRESSURE CONTROL VALVE
PI	-	PRESSURE INDICATOR
PLEM	-	PIPELINE END MANIFOLD
POSN	-	POSITION
PR	-	PRESSURE RECORDER
PS	-	PRESSURE SWITCH
PT	-	PRESSURE TRANSMITTER
QR	-	QUANTITY RECORDER
SI	-	SPEED INDICATOR
SP	-	SAMPLER
SPM	-	SINGLE POINT MOORING
SR	-	SPEED REGULATOR
SS	-	SIGNAL SELECTOR
SW	-	SWITCH
TI	-	TEMPERATURE INDICATOR
TS	-	TEMPERATURE SWITCH
TT	-	TEMPERATURE TRANSMITTER
ULCC	-	ULTRA LARGE CRUDE CARRIER
VIB SW	-	VIBRATION SWITCH
VLCC	-	VERY LARGE CRUDE CARRIER
XA	-	ALARM

SYMBOLS

 PRODUCT PIPING LINES WITH BLANK ENDS

 CONNECTION TO PRODUCT, OR MECHANICAL LINK, OR INSTRUMENT SUPPLY

 PNEUMATIC SIGNAL

 ELECTRIC SIGNAL

12211 ← EQUIPMENT STAGING NUMBER

LOCALLY MOUNTED INSTRUMENT

BOARD MOUNTED INSTRUMENT

12211 ← EQUIPMENT STAGING NUMBER

INTERLOCK

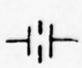
 MOTOR OPERATED VALVE

 BALL VALVE

 FLOW CONTROL VALVE

 CHECK VALVE

 GATE VALVE

 FLOW MEASURING DEVICE (ORIFICE PLATE)

 'AND' GATE

 'OR' GATE

(12000) EQUIPMENT STAGING HIERARCHICAL NUMBER

1.0
INTRODUCTION

1.1 STUDY OBJECTIVES

In light of the importance of the safe and efficient transfer of oil in Deepwater Ports (DWPs), it was the intent of this study to examine in detail the oil transfer control system in order to aid the design review process. Specifically, the objectives were:

- to evaluate normal procedures and controls used in DWP crude oil transfer operations
- to evaluate types of failures that might occur in the control system
- to evaluate emergency procedures and controls which would be employed when normal procedures and controls are inoperative.

With offloading rates in DWPs approaching 300,000 barrels per hour, the performance and reliability of the oil tranfer equipment and controls are of critical importance. Reaction times previously adequate in lower volume systems are inadequate in the specification of a modern Deepwater Port.

With increasing loading rates, there has been a steady shift in control technology towards automatic and electronic control systems. This changing state-of-the-art makes it difficult for those evaluating, reviewing, and approving control system designs to assure that certain minimum standards are met.

1.2 STUDY APPROACH

The first step in the study was to describe a Deepwater Port. The one described consists of the following major systems:

- Tanker
- Offshore Facilities (Platforms and SPM 's/Sea Island)
- Onshore Facilities
- Communications

Once the major physical systems were determined, a Functional Staging Diagram (FSD) was developed. The FSD is a hierarchical block diagram structure which is used to determine and display the interdependency of functions necessary for a system to operate (see 2.3.2 for a complete description).

Equipment Staging Diagrams (ESD) were then constructed for a Deepwater Port utilizing the generic functions of the FSD as a guide (see 2.3.3 for a complete description of ESD). The ESDs evolved from a top down approach in which systems were described in terms of subsystems, elements, and equipment.

Ordinarily, the next step in the approach would have been to construct Operational Sequence Diagrams (OSD) which are useful in displaying information-decision-action relationships in highly complex systems. Several factors contributed to shifting from OSDs to a Failure Modes and Effects Analysis (FMEA). One of the primary reasons was that the DWP oil transfer control system was not as complex as was originally anticipated. This was combined with the fact that the oil transfer control system's operational

sequence of system lineup, movement of cargo, and shutdown were readily displayed in the ESDs. The detailed equipment sequences, if available, were described in the FMEA.

Multiple Activity Charts (MAC) are useful in analyzing scheduling problems, work load balance and manpower utilization in specific and complex systems. Because of the generic nature of the DWP described herein, MACs were not considered the appropriate means of displaying the information. Instead, a more qualitative method is used in the narrative description of oil transfer control systems.

As the study progressed through the definition phase, which included the hierarchical description of the offloading process and its associated equipment, it became apparent that the best way to meet the reliability objectives was through a combination of Fault Trees and Failure Modes and Effects Analysis. This provided a blend of theoretical and operational points of view with the emphasis placed on operational and design experience since the intended user was a design reviewer. Reliability Block Diagrams could have been used in lieu of Fault Trees, but it was determined that the explicitness of Fault Trees (especially since they were not complex) would be easier to understand and would be more flexible under changing design than would be Reliability Block Diagrams.

The Failure Modes and Effects Analysis emphasized extremely important aspects of oil transfer control systems, based on actual operational experience. Failure modes were explicitly described, alternative procedures which would mitigate either the failure or the effects of the failure were synthesized by

knowledgeable design experts, and scenarios were postulated which quantified the spill sizes which could result from critical equipment failures. Maintenance actions were recommended which would keep the equipment as close to designed condition as possible.

1.3 REPORT STRUCTURE AND USES

The primary intended user of this report is the design reviewer in the United States Coast Guard. The information presented is structured to provide the reviewer first with specific descriptive material and then with the means to use this material so that an informed decision can be made as to the acceptability of a design.

Section 2.0 provides the specific background material, Section 3.0 describes the Numerical Rating System, and the Appendices contain further backup material and worksheets.

Section 2.0, System Characterization, is functionally oriented, and it is formatted around a hierarchical DWP equipment structure. This makes it possible for the reviewer to obtain information knowing either the physical structure or the functional structure. For example, the design reviewer could directly obtain information on an overspeed trip used by a tanker by looking at ESD 11200 and finding that the overspeed trip is number 11213/01. The review could then turn to Section 11213/01 in Appendix E for more information. On the other hand, the reviewer might not know that an overspeed trip was required. The reviewer could still get information on it by searching the functional headings of Pump Protection Devices, Start Pumping, or Move Oil Through Tanker Systems.

In this report, the location of the DWP Central Control Station has not been fixed. This is deliberate because there is no generally accepted practice within the industry which locates the central control of a terminal in any one place. Existing Deepwater Ports show a variety of locations determined by whether or not the DWP in an extension to existing facilities, by the distance between the on and offshore facilities, or by the established practices of the owner(s).

Wherever "Central Control Station" is referred to in this report, its location can be ignored; the communications link completes the "loop" of those control systems considered and the location becomes irrelevant.

Section 3.0, the Numerical Rating System, is an extension of Section 2.0 in that the reviewer will draw upon the concepts and criteria presented to describe the system being evaluated and to numerically rate this proposed system against the benchmark system of Section 2. The rating system is comprised of two major parts: the Design Adequacy Rating and the Reliability/Effects Rating. An example of how to use the Rating System is given to aid in the understanding of the procedure.

The Appendices contain various backup material including:

A. Failure Modes and Effects Analysis of the control system presented in Section 2.0. This analysis is a systematic procedure which identifies and assesses the likelihood, consequences, and corrective action which should be taken for significant modes of failure.

B. Fault Trees of the control system identified in Section 2.0, including equations which quantify the equipment relationships of the fault tree to determine the element probability of failure.

C. Element Reliability/Effects Rating Sheet, including a blank set for the design reviewer and a completed set on the control system identified in Section 2.0.

D. Effects Rating Factor Worksheet, including a blank set for the use of the design reviewer and a completed set on the control system identified in Section 2.0.

E. Equipment Description, including:

A general section which discusses the type of instrumentation used in the control systems.

A section dealing with information in the form of technical manual excerpts.

A section devoted to the specific components of the control systems.

F. Scenarios of Failure of vital elements and their resultant effects.

1.4 DEEPWATER PORTS

Deepwater Ports, as defined in the "Deepwater Port Act of 1974," are:

"...any fixed or floating manmade structures other than a vessel, or any group of such structures, located beyond the territorial sea and off the coast of the United States and which are used or intended for use as a port or terminal for the loading or unloading and further handling of oil... The term includes all associated components and forms, mooring buoys, and similar appurtenances..."

This study considers the Control Systems of those ports covered by The Act and designed only for the offloading of oil.

Two distinctly different types of offshore facilities exist and are in operation today, although the fundamental function of the port remains the same. These are:

1. Single Point Mooring
2. Sea Island

The Control Systems of a Deepwater Port are concerned with two major functions:

1. The actual transfer, measurement and control of the oil.

2. The prevention and minimization of any adverse impact from failure of the oil transfer system.

A narrative description of the basic functions of a Deepwater Port and a discussion on the development of the various diagrams used in this report can be found in Section 2.0.

1.4.1. TANKERS

The control systems associated with the handling of VLCC crude oil cargoes are concerned with:

- Levels in the tanks
- Cargo pumps
- Stripping pumps
- Valve operation

Investigations have revealed that these controls are kept as simple as possible and apart from pump protection devices which automatically shut down the pump under abnormal conditions, no other automatic control loops are installed.

Remote control from a central control room is common on today's tankers. From this central location, the ship's crew control the main cargo and stripping pumps, switch tanks according to the remote level readings and operate the valves required to route the oil from the tanks via the pumps to the ship's manifold. Details of the component parts of these control systems are fully described in Appendix E.

1.4.2 OFFSHORE FACILITIES

1.4.2.1 Platforms and Single Point Moorings (Figure 2-1)

This type of facility utilizes a buoy or floating turntable to which the tanker is moored "bow on." Floating flexible hoses connected from the ship's manifold to a swivel on the S.P.M. provide the flexible link between the tanker and the Deepwater Port facilities.

Block valves on the seabed at the pipeline end manifold (PLEM) provide the necessary isolation in the event of an emergency. Single Point Moorings can be connected directly by submarine pipeline to shore facilties, or they can be part of a complex involving an intermediate pumping platform and other S.P.M.s.

The Control Systems on an S.P.M. platform, which includes booster pumps and/or metering facilities, are extensive and complex.

If the terminal facilities are such that the rapid closure of a valve or the quick starting or stopping of a pump could propagate a surge pressure condition, then a surge relief system should be included. Various monitors and controls are necessary to ensure the function and availability of this relief system at all times.

It is normal practice to install a block valve at the platform end of each submarine pipeline to shore. This valve serves the purpose of emergency shutdown of the facilities effectively isolating, for instance, a ruptured submarine pipeline from the tanker. This valve would also be used to provide a pressure shutoff for pipeline leak testing.

1.4.2.2 Sea Island (Figure 2-2)

This type of Deepwater Port provides a fixed structure against which the loaded tanker berths and is moored. Fully articulated loading arms are connected to the ship's manifold and provide the flexible link between the tanker and the piping systems on the structure. These loading arms will, within certain limitations, follow the movement of the tanker as it unloads its cargo.

The controls associated with the piping systems on the central platform of the Sea Island can be simple, monitoring only pressures and flow rates, or they can be complex and comparable to those described for an S.P.M. platform. The same control systems would be required for booster pumps, metering, and surge relief as that found on the S.P.M. platform.

1.4.3 ONSHORE FACILITIES

Large tank farms containing numerous tanks or underground storage cavities are necessary to store the cargoes of oil discharged from VLCCs. The pipelines from these tanks are connected to the submarine lines through a valve manifold which, as the number of submarine lines and tanks increases, becomes more complex. Electrical interlocks become necessary to prevent the accidental opening of valves and to ensure the correct routing of the oil through the onshore facilities. Where the tank farm is some distance from the shore, the installation of booster pumps may be required in order to move the oil to storage. Custody transfer or leak detection would require the inclusion of a metering station and, where the possibility of surge pressures exist, a protection system would be included. The levels in the tanks are continuously monitored by level instruments which, in exceptional cases, may be used to determine volumes for custody transfer. However, these remote reading level instruments are used mainly as an operational tool to prevent overfilling and overemptying.

1.4.4 COMMUNICATIONS

This essential link between the basic components of any Deepwater Port can be achieved in many ways.

In this study, only the communications which play a part in the control systems are considered.

Where the offshore facilities are only a short distance from shore, a communications submarine cable is laid on the seabed. An economic break point exists, however, as the distance offshore became greater. At this point, it becomes more economical to install a communications radio link. Both types will carry voice as well as instrumentation signals.

As the facilities become more and more complex involving an interchange of many signals, a system of coded communications is necessary. These coded signals may be transmitted by either the submarine cable or radio.

2.0

SYSTEM CHARACTERIZATION

2.0
SYSTEM CHARACTERIZATION

2.1 INTRODUCTION

This section deals with the basic functions of a DWP and explains the development of the Line Diagrams, Functionnal Staging Diagram and Equipment Staging Diagrams contained in this report. The method employed to develop these diagrams was based upon the progressive expansion of successive diagrams until a detailed list of components was obtained.

The initial Line Diagrams (Figures 2-1 and 2-2) show the two types of Deepwater Ports considered in this report. It is from these two basic diagrams that all other Line Diagrams have been developed.

The Functional Staging Diagram (Figure 2-3) takes the operational sequence of the functions required in moving oil from the tanker to the onshore storage and displays it as a three-level hierarchical block diagram. It is from a combination of these two basic Line Diagrams and the Functional Staging Diagram that the Equipment Staging Diagrams were developed.

A logic numbering system was developed to identify the individual functions and components of the Equipment Staging Diagrams, and to serve as a cross-reference throughout this report.

2.2 DWP BASIC FUNCTIONS

The following narrative is designed to familiarize the reader with the basic operational techniques and equipment employed in importing crude oil at a Deepwater Port. It is assumed that the tanker is moored or berthed and that the connection to the hoses or loading arms has been completed.

2.2.1 PREPARATIONS

The first step in the actual offloading of oil requires that equipment on the tanker and at the offshore and onshore facilities be made ready and "lined-up" to receive the oil.

On the tanker, the piping systems from the tanks to the suction of the pumps must be prepared by opening the appropriate valves. A sequence of tanker cargo tank emptyings will be followed which maintains the ship at an acceptable trim. This means that tank levels must be continuously monitored and when required, the tanks must be switched to and from the pump suction systems. The piping route from the pump's dis·harge to the ship's manifold must be prepared by opening the appropriate valves.

The offshore facilities, whether they be a platform complex serviced by S.P.M.s or a sea island, must also be made ready to receive the oil from the tanker. The necessary valves must be opened to route the oil to the submarine pipes which will carry it ashore. If the facilities include booster pumps and metering stations, then these also must be readied to receive the oil. The

appropriate valves must be opened to route the oil to the booster pumps and/or the selected meters. The automatic sampler must be adjusted and made ready to extract the proper quantity of oil from the pipeline for analysis.

It is normal practice to leave one valve in the system closed. On a platform complex served by S.P.M.'s, this valve would be the isolating valve at the top of the submarine pipe riser; for a sea island platform, it would be the valve at the base of each loading arm.

At the same time, the onshore facilities must be "lined-up" to route the oil to the receiving storage tanks. This may be via a booster pumping station and/or a metering station.

The need for booster pumping is determined by the distance the oil has to travel.

Metering stations serve dual functions; to precisely measure the quantity of oil being transferred for custody purposes and/or to compare offshore metered measurements with onshore metered measurements as a means of detecting leaks.

Before pumping commences, the surge protection equipment, if installed, must be checked and made ready to deal with a surge if it should occur.

2.2.2 PUMPING

At the request of the terminal operators, the ship starts pumping at a very low flow rate. This causes a pressure build-up against the closed submarine pipe riser or loading arm valve(s) on the offshore facilities.

This procedure tests the hose or loading arm connections to the ship's manifold. If the connections prove leak tight, the pipe riser or loading arm valve is opened. The ship is then requested to increase its pumping rate in stages until the authorized offloading flow rate has been attained.

As the ship's storage tanks empty, full tanks must be brought onto line. The ship's operators monitor the levels in the tanks and control the opening and closing of tanker valves from the ship's central control room. This control room also houses the controls and indicators for the main cargo and stripping pumps.

The most common type of pump prime mover employed on VLCCs is the steam turbine. This type of prime mover has the advantage of variable speeds, thus being able to control the rate of pumping over a large range.

Once the oil moves from the ship, port operating personnel monitor and control the flow from a central control room. It is normal practice to group all controls on a mimic control panel which, apart from housing the controls and indicators, has a mimic display of the piping system on the platform.

DWP oil transfer systems which are required to accommodate multiple crude oils that cannot be contaminated with each other are provided with a "pigging" system. Separation of crude oil cargoes is accomplished by placing a pig at the interface of the two crude types. In this way, both crudes are transferred through the transfer systems simultaneously.

Pigs are available in many shapes and they can be fabricated from various materials. For DWP service, spherical pigs made of neoprene are the most widely used. A more detailed description of pigging systems is given in Appendix E.

When booster pumps are necessary to assist the ship's pumps in moving the oil ashore, automatic controls ensure that the flow rate and system pressure are synchronized with the ship's pumps.

Metering stations which are continuously measuring the quantity of oil passing through the facilities are monitored from the central control room where flow rates, accumulated quantities, pressures and proving procedures are displayed and controlled.

Alarms and remote indicators warn the operators if the surge protection system, when installed, is available to deal with a surge situation.

2.2.3 SHUTDOWN

As the level in each of the ship's tanks is reduced, full cargo tanks are brought on line. Relatively small quantities of oil remain in the tanks at levels below the suction capabilities of the main cargo pumps. This oil is removed from the tanks and pumped into the piping system by a series of small pumps called "stripping pumps." This stripping operation usually occupies the last hour or so of the discharging time. The main cargo pumps are shut down as "stripping" begins.

When stripping is complete, the oil in the ship's manifold is allowed to drain back to the tanks and the valves are closed. In the case of operations at an S.P.M. facility, each hose valve is closed including the undersea valve at the PLEM. The hose is then disconnected from the ship and capped while filled with oil (they are drained only prior to a storm). For a Sea Island operation using loading arms, the outboard arm is allowed to drain back to the ship before disconnection takes place; the inboard arm is drained to the platform slop (drainage) system.

At the conclusion of cargo transfer to shore storage, the facilities are shut down in a sequence which ensures that the piping system is "packed" with oil. This sequence of valve closing starts at the SPM's or loading arms and finishes at the storage tank onshore.

Booster pumps, in parallel operation at a given station, if installed, are shut down one at a time as the flow rate decreases. Likewise, the meters, in parallel operation, if installed, are taken off-line as the flow rate decreases. The onshore facilities are also shut down in a similar sequence and manner. The final levels in the receiving storage tanks are noted and the total quantity computed.

2.3 DEVELOPMENT OF DIAGRAMS

2.3.1 LINE DIAGRAMS

The text of this report has been supplemented by the inclusion of a series of pictorial presentations in the form of Line Diagrams. These are simple one line diagrams, drawn isometrically for clarity, which lend themselves to a

progressive expansion whereby each succeeding diagram reveals further detail until all the component parts of the control systems appear.

Beginning with the two basic diagrams (Figures 2-1 and 2-2) which illustrate the major component parts of a Deepwater Port, further diagrams have been developed on a sequence basis which follows the route of the oil from the tanker to the onshore storage facilities.

The major components of a DWP--tanker, offshore facilities and onshore facilities--have been dealt with individually and within themselves have been broken down to show the various control systems involved.

The next step in this progression was to develop Line Diagrams which show the component parts of each control system. At this stage, it became possible to prepare Equipment Staging Diagrams which are discussed in further detail later in this section.

2.3.2 FUNCTIONAL STAGING DIAGRAM

Concurrently with the development of the basic line diagrams, a Functional Staging Diagram was produced (Figure 2-3). This takes the form of a hierarchical block diagram. The purpose of the diagram is to show how the basic requirement to transfer oil is broken down into the functional details of moving oil from the tanker through the offshore and onshore piping systems, and finally to the onshore storage facilities. The basis upon which this diagram developed depended on the established operational technique presently in use at existing Deepwater Ports. This takes into account the preparation of the major component parts to receive the oil, the movement

of the oil through them and the shutdown sequence upon completion of the operation. Not only has the normal operational shutdown been considered but also the case of emergency shut down where protective controls come into play.

The Communications System, although not a separate functional component, is so intricately woven into the fabric of the overall operation that it has been included at this level rather than at the equipment level where some of its importance could be lost.

2.3.3 EQUIPMENT STAGING DIAGRAMS

These diagrams are the product of both the Line Diagrams and the Functional Staging Diagram. Each of the lower level functions shown in Figure 2-3 head their own breakdown of the equipment components for the various control systems required to perform those functions.

All functions and equipment components are shown on the equipment staging diagrams in a hierarchical manner, such that all are identified by a logic numbering sequence which is described and explained later in this section.

Appendix A contains the Failure Modes and Effects Analysis (FMEA's) which lists each piece of equipment, its function, potential failure modes, effects of failure, reliability and recommended corrective action.

2.3.4 NUMBERING SYSTEM

The logic employed in the numbering system presented in the Equipment Staging Diagrams is set to follow a hierarchical sequence.

The numbering system is based upon utilizing a five-digit number. For the purposes of the explanation, the five-digit number is represented by the following five letters:

<u>A</u> <u>B</u> <u>C</u> <u>D</u> <u>E</u>

A is given the value one. This signifies that the function is the import of oil. A further functional breakdown is given by B. B is numbered:

1. Discharge oil from tanker
2. Move oil through offshore piping
3. Move oil through onshore piping

For example, a number given the value 12000, can be understood to be the import of oil through offshore piping. C is designed to give a further functional breakdown of the import of oil through the tanker, offshore and onshore systems. C is a number:

1. Line-up system
2. Move oil through system
3. Shutdown system
4. Communications system

Now 12200 can be understood as the moving of oil through the offshore piping system.

D separates C into further functional categories. These categories are too numerous to list, but they can be found through study of the equipment staging diagrams found later in this report. For example, 12240 can be understood to mean that during the movement of oil in the offshore piping system there exists a system for the relief of pressure surges.

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A B C D E

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Lastly, E signifies the equipment function. For example, 12241 is known as the Surge Relief Availability Control consisting of a valve actuator.

This, in short, is a summary of the numbering system logic used in this report.

2.3.5 CONTROL SYSTEM DIAGRAMS

The remainder of this section contains a graphical representation of the benchmark control system which was developed for use in the Numerical Rating System of Section 3.

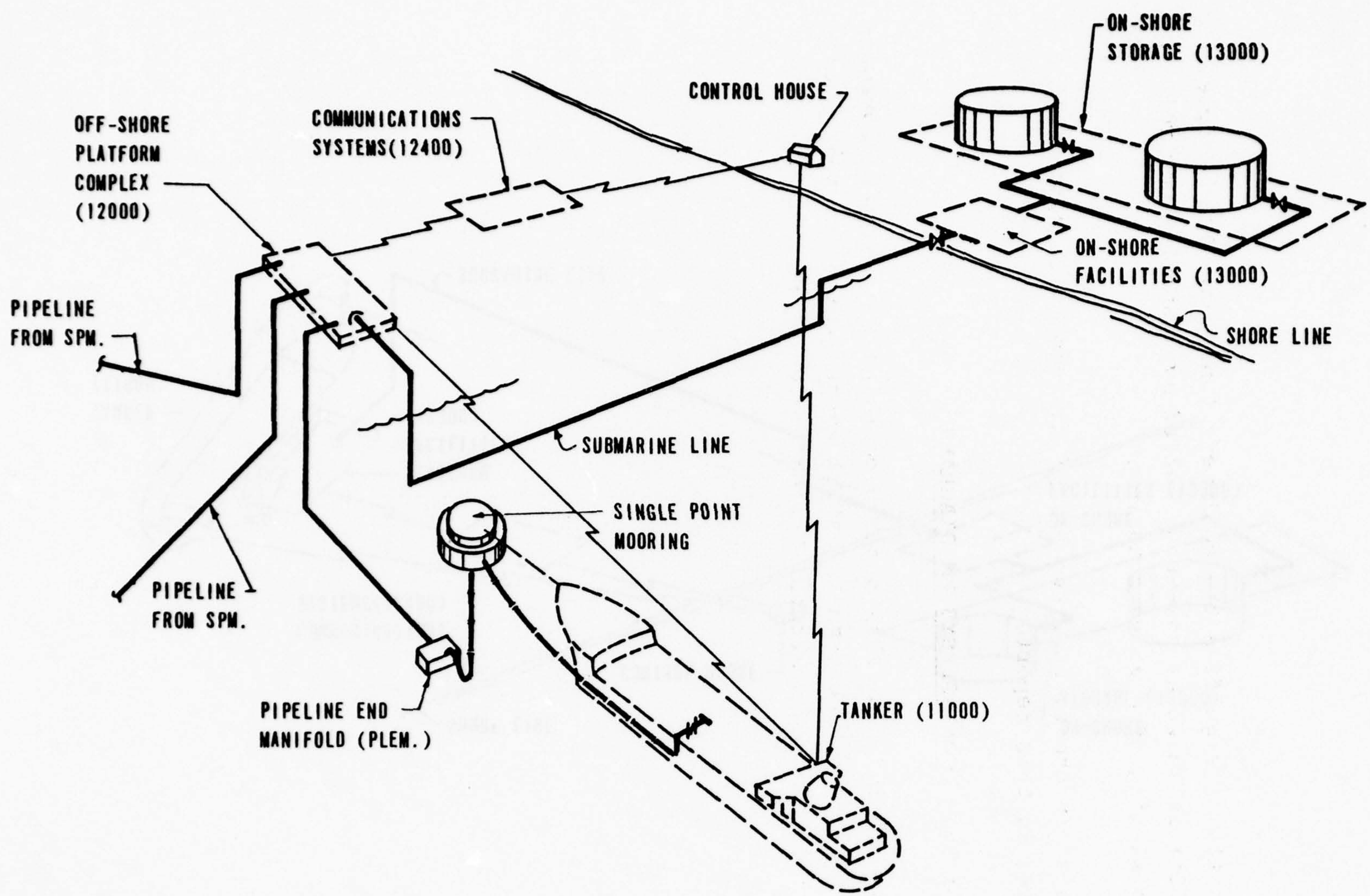


FIGURE 2-1, SINGLE POINT MOORING - BASIC LINE DIAGRAM (10000)

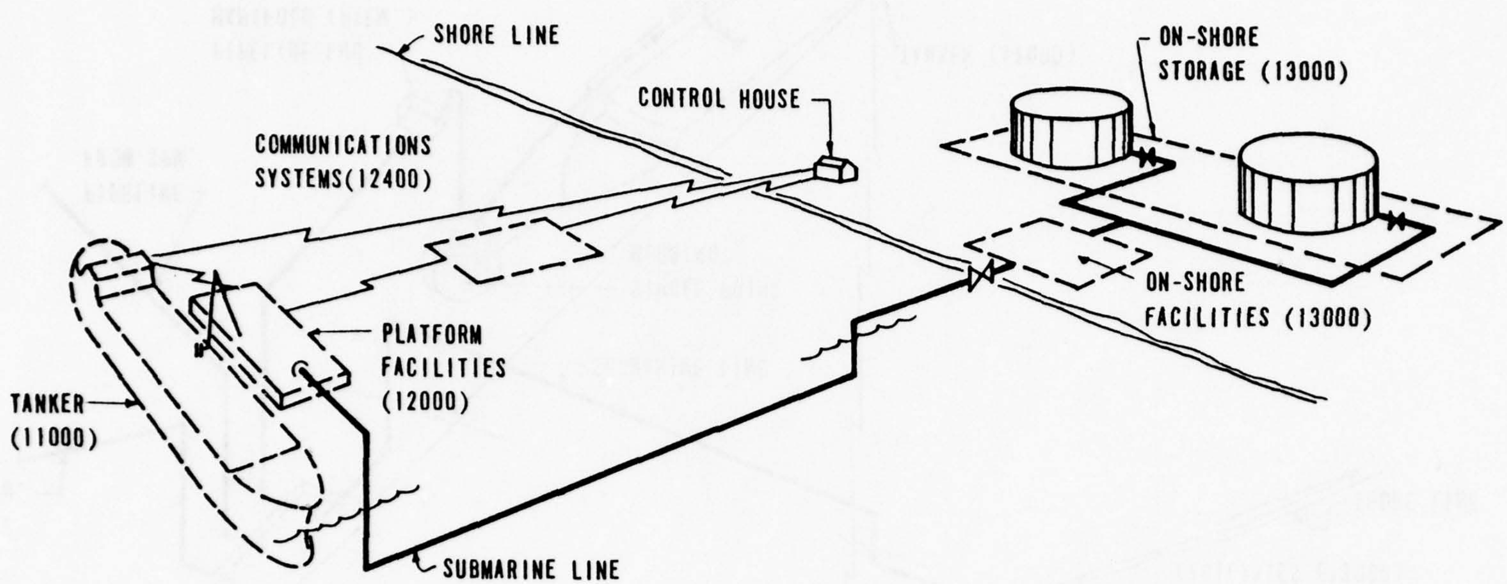


FIGURE 2-2, SEA ISLAND - BASIC LINE DIAGRAM (10000)

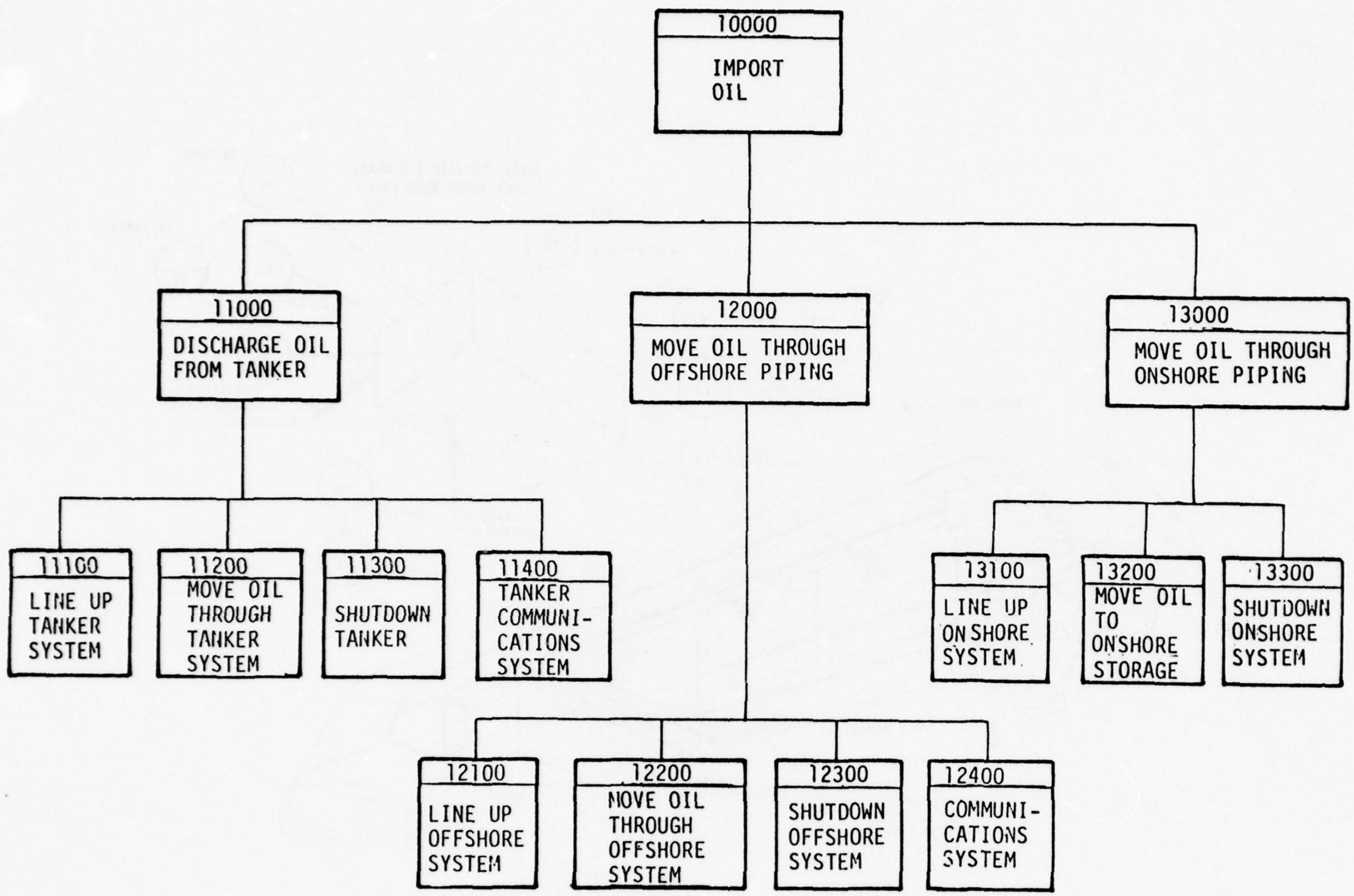


FIGURE 2-3, FUNCTIONAL STAGING DIAGRAM -

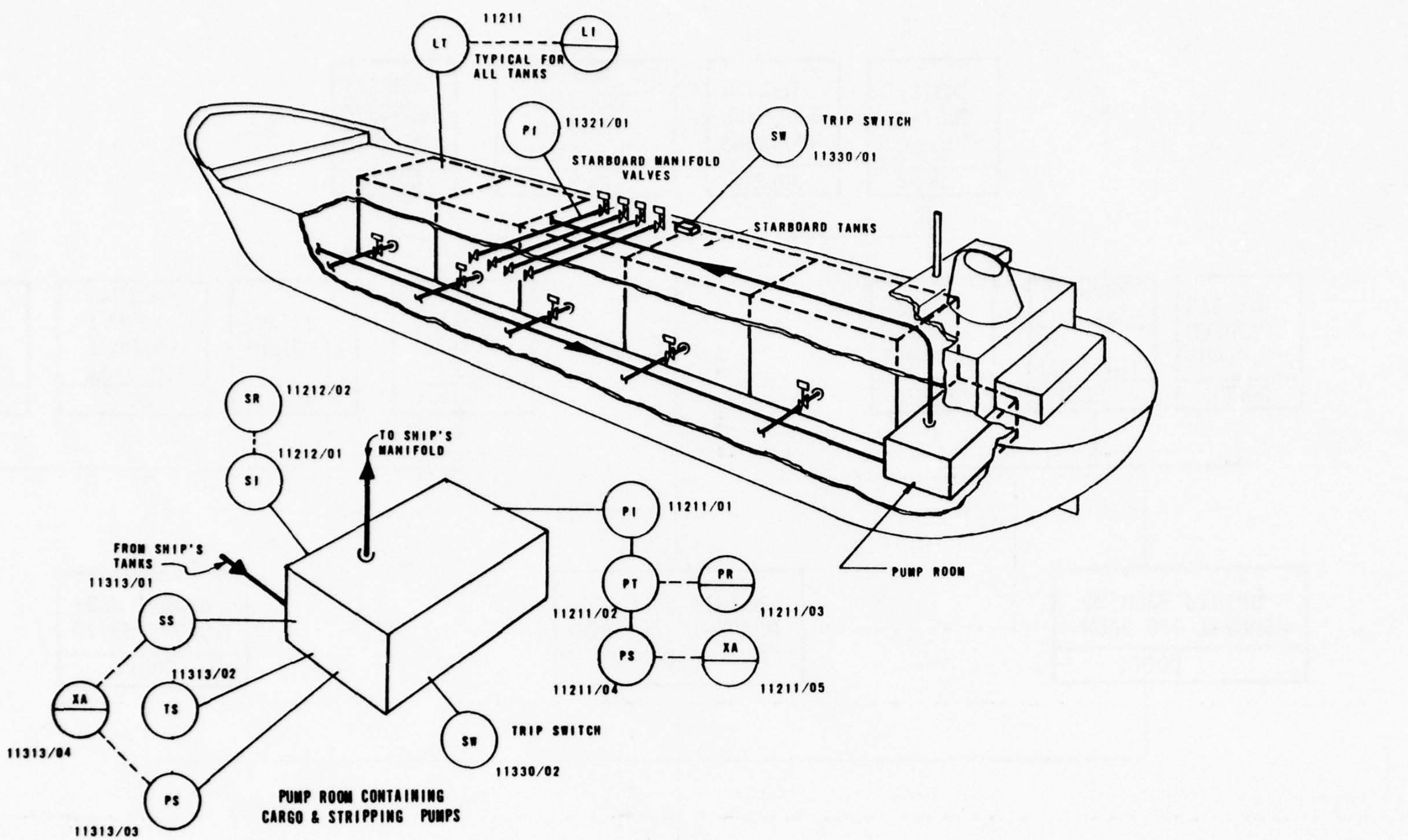


FIGURE 2-4, TANKER CONTROLS (11000)

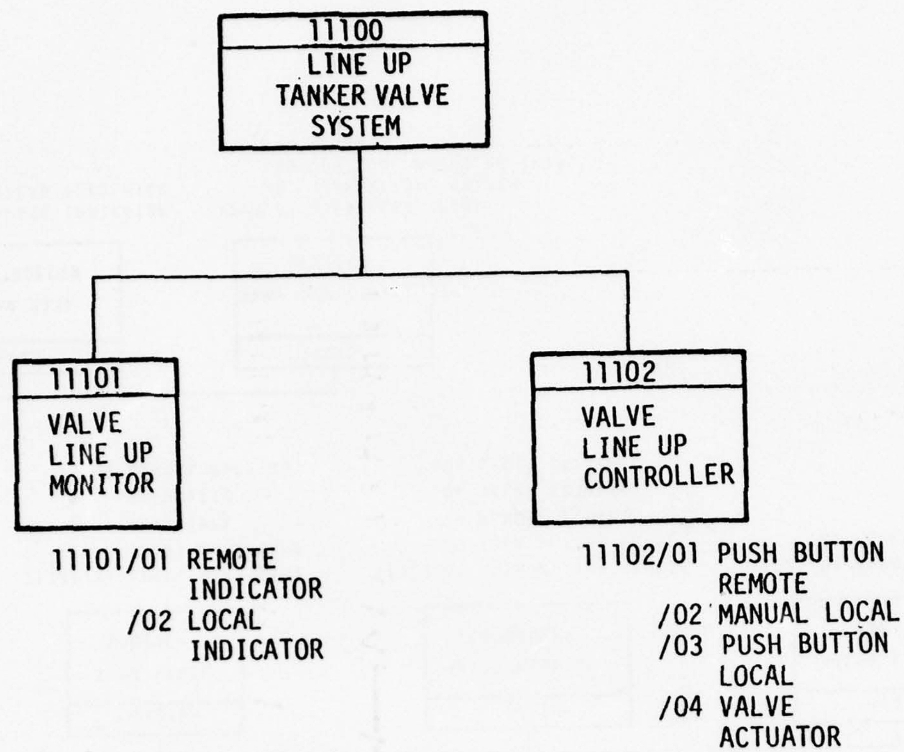


FIGURE 2-5, LINE-UP TANKER VALVE SYSTEM - 11100 ESD

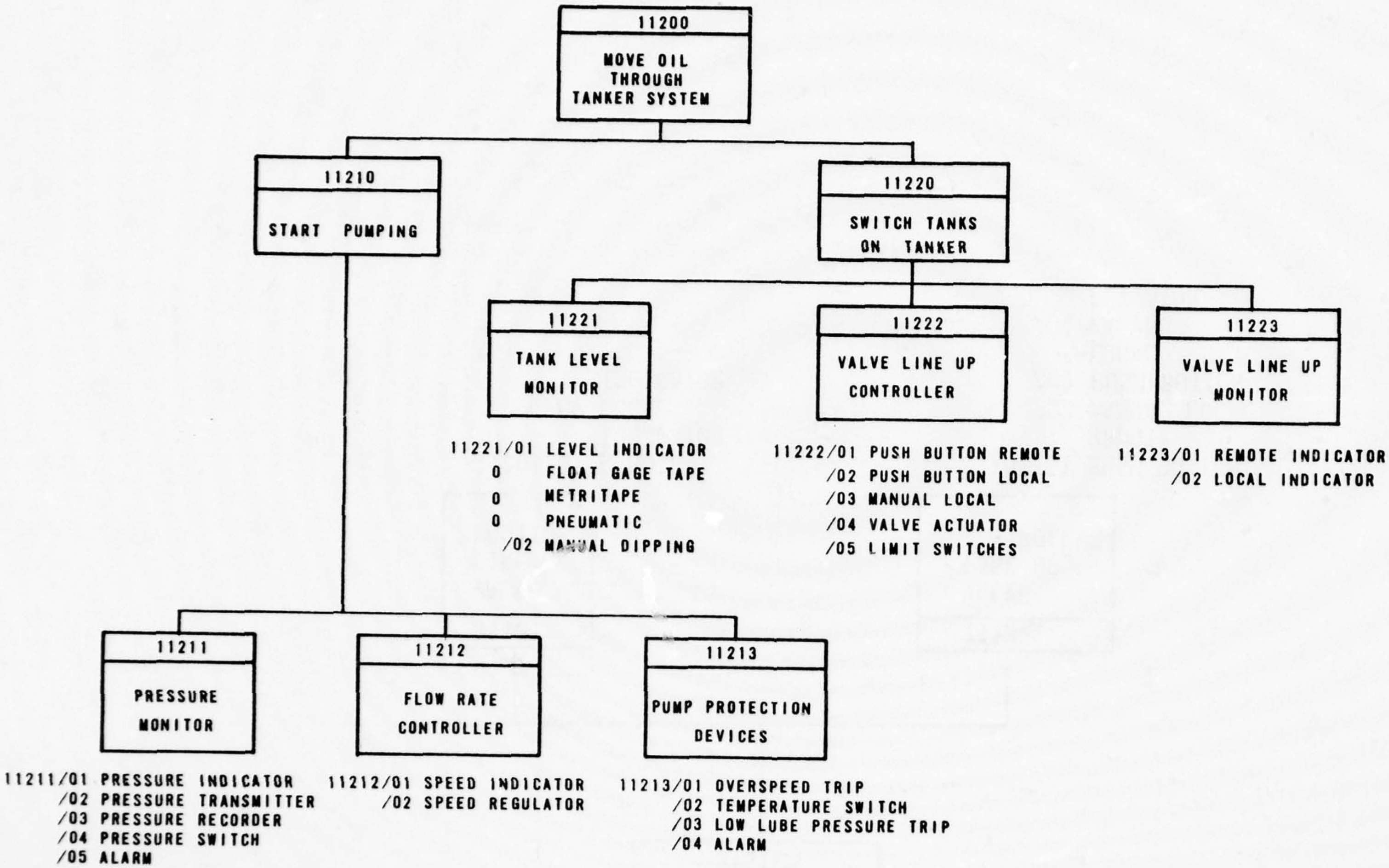


FIGURE 2-6, MOVE OIL THROUGH TANKER SYSTEM - 11200 ESD

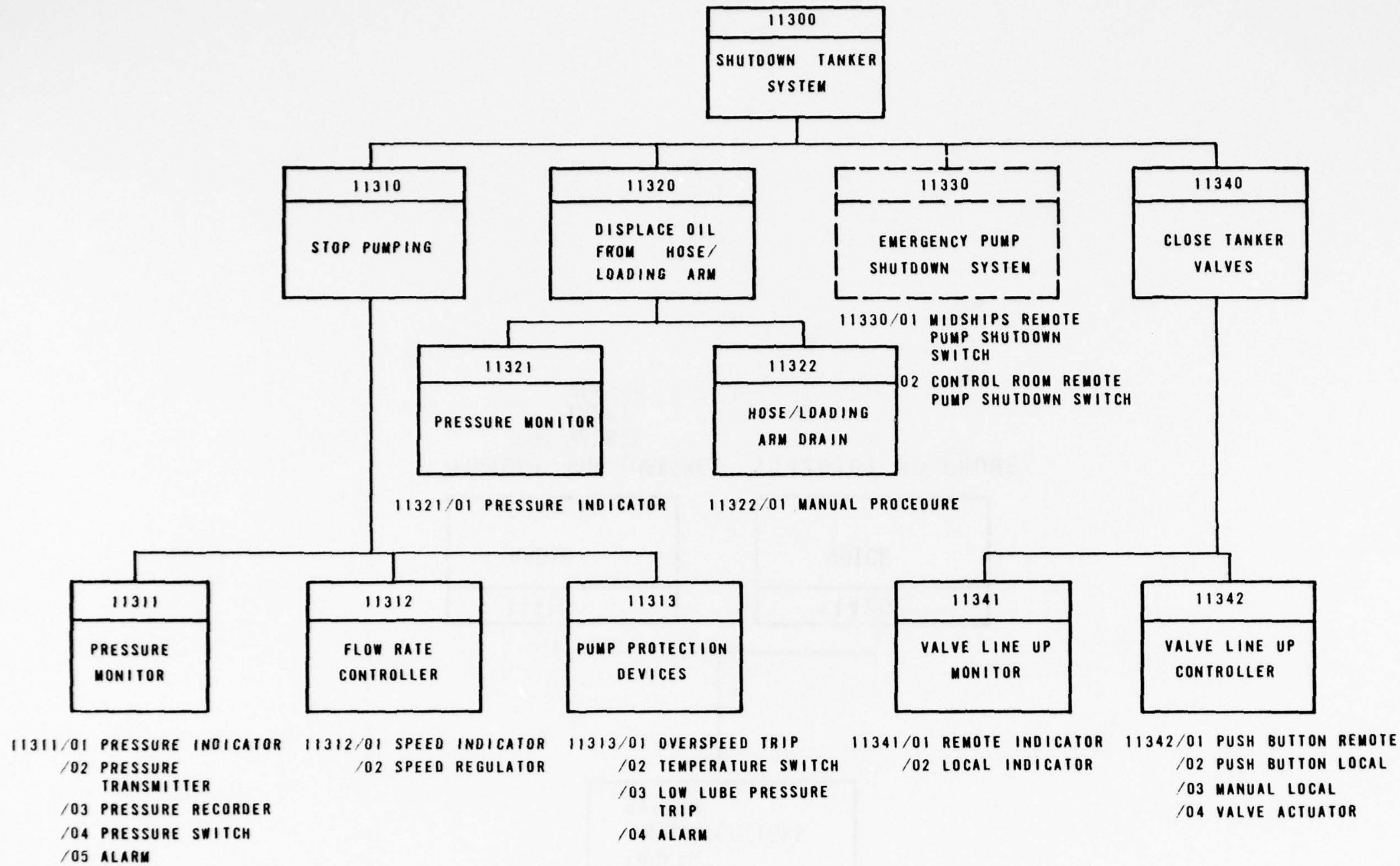


FIGURE 2-7, SHUTDOWN TANKER SYSTEM - 11300 ESD

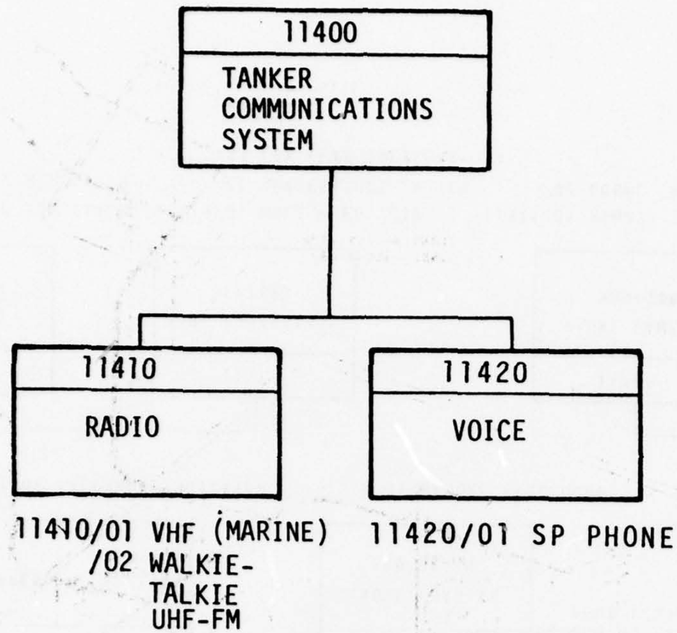


FIGURE 2-8, TANKER COMMUNICATIONS SYSTEM - 11400 ESD

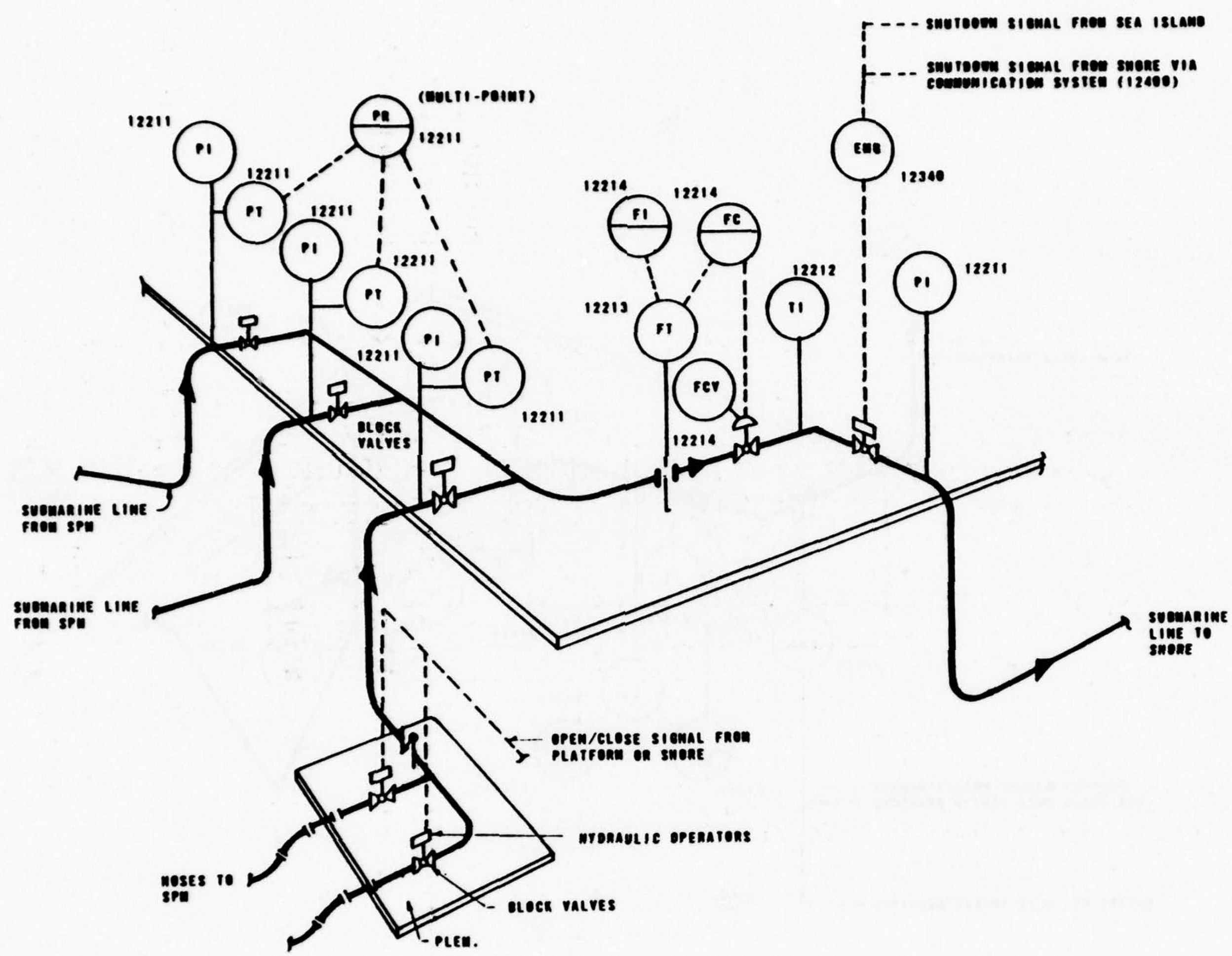


FIGURE 2-9, S.P.M. BASIC PLATFORM (12000)

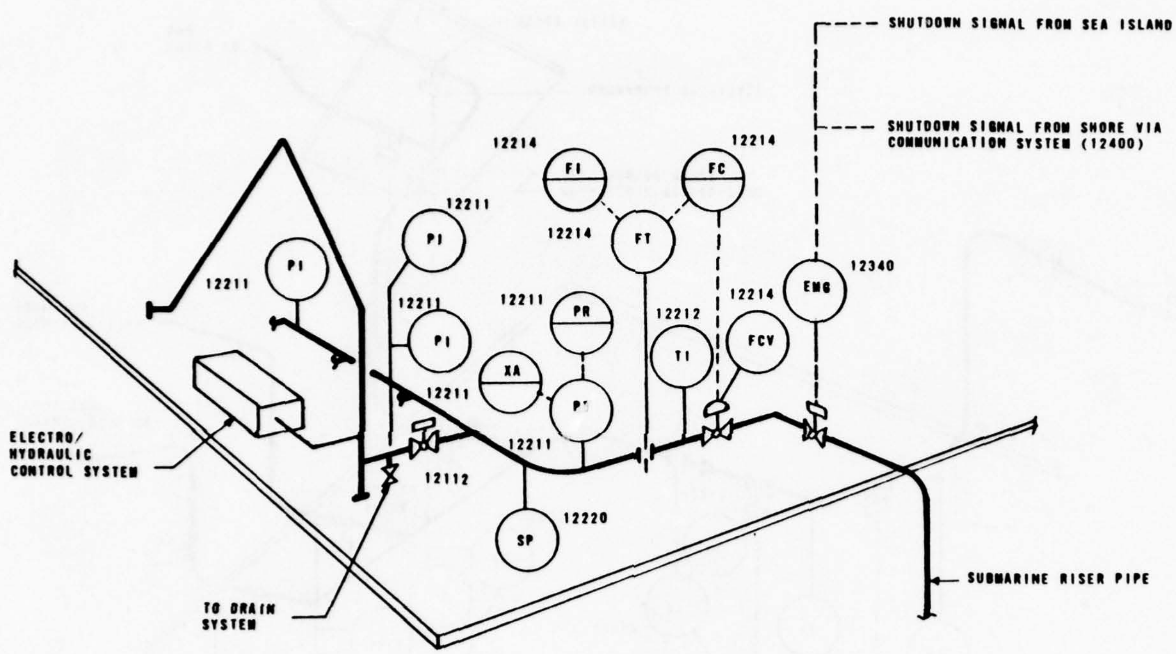


FIGURE 2-10, LINE-UP OFFSHORE SYSTEM - 12100 ESD

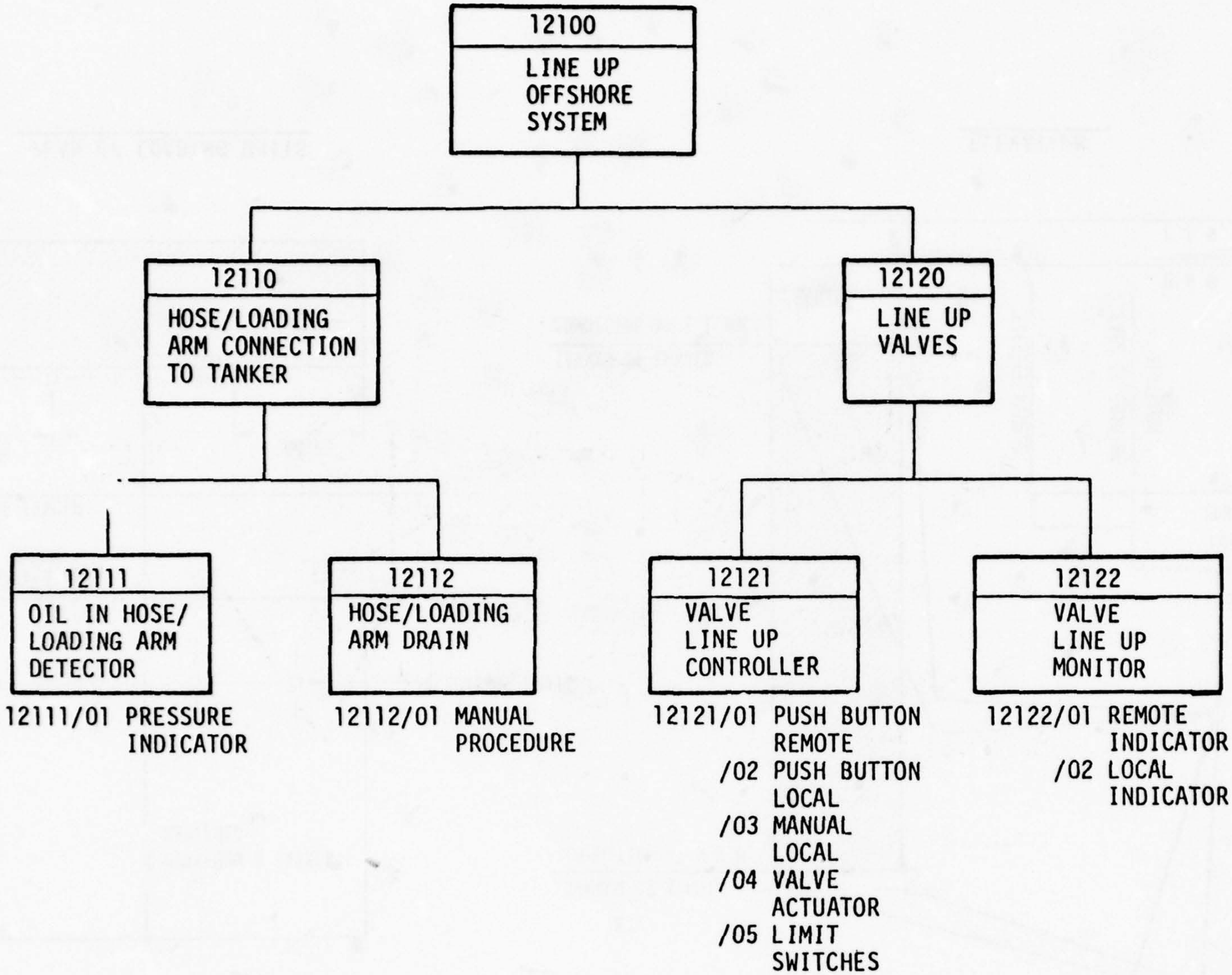
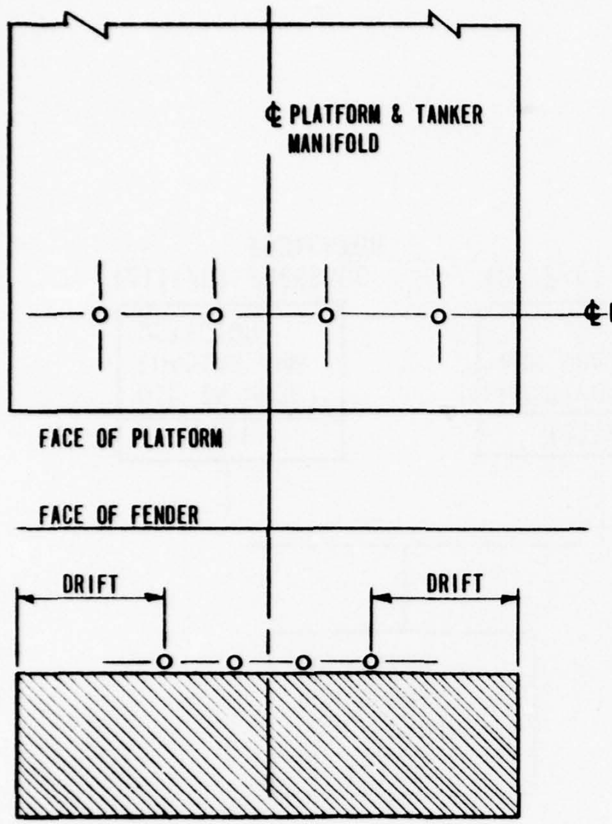
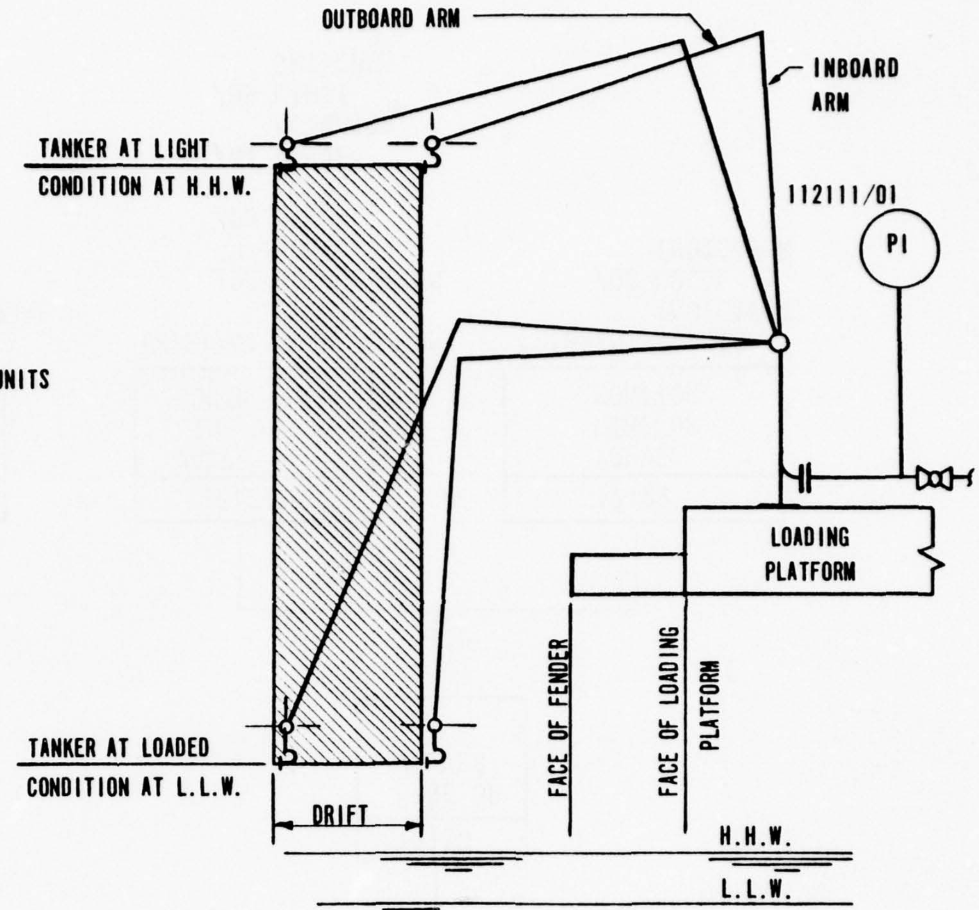


FIGURE 2-11, LINE-UP OFFSHORE SYSTEM - 12100 ESD



PLAN OF LOADING UNITS



ELEVATION

FIGURE 2-12, LOADING UNIT RANGE & DRIFT DIAGRAM (12110)

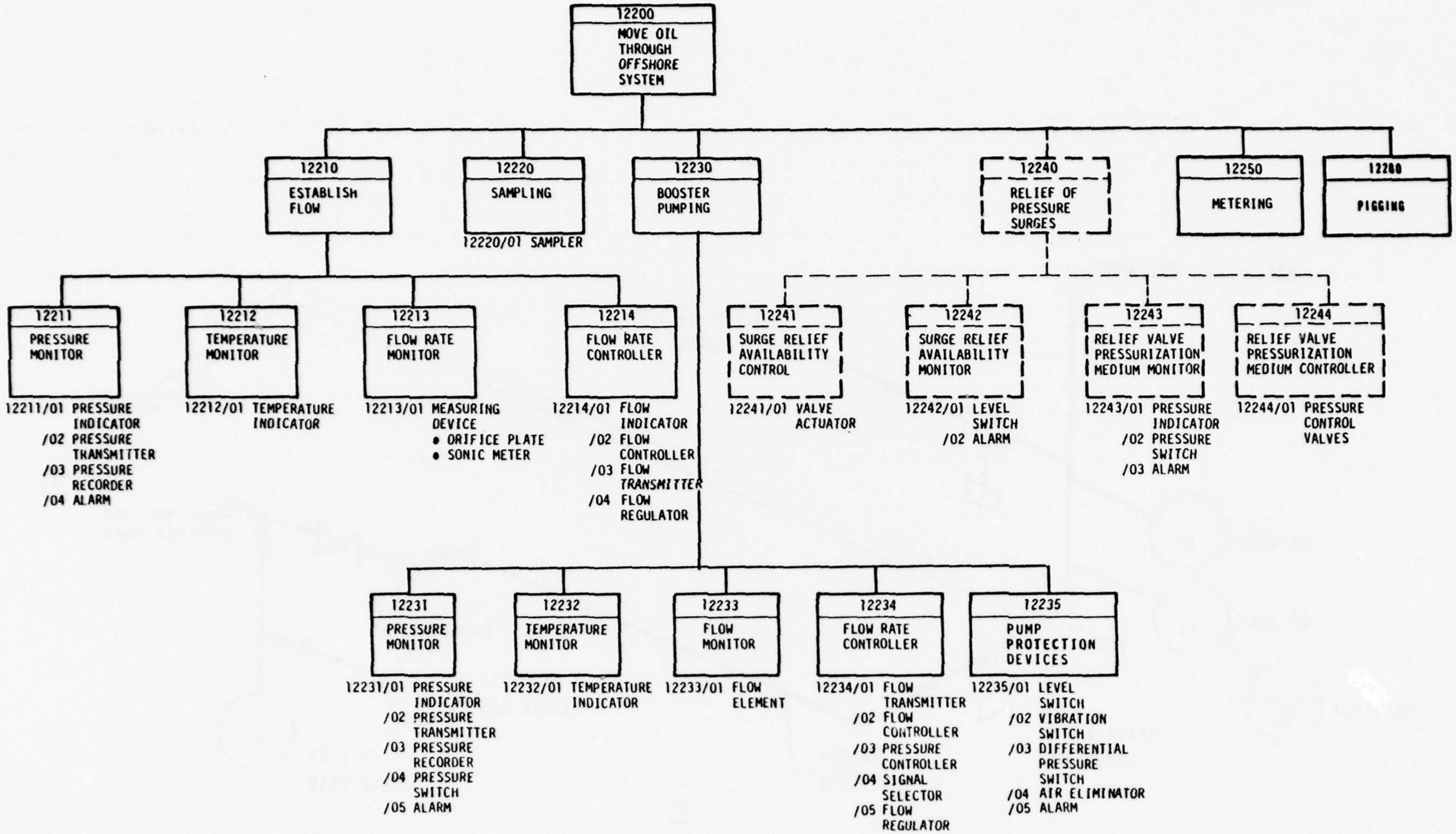


FIGURE 2-13, MOVE OIL THROUGH OFFSHORE SYSTEM - 12200 ESD

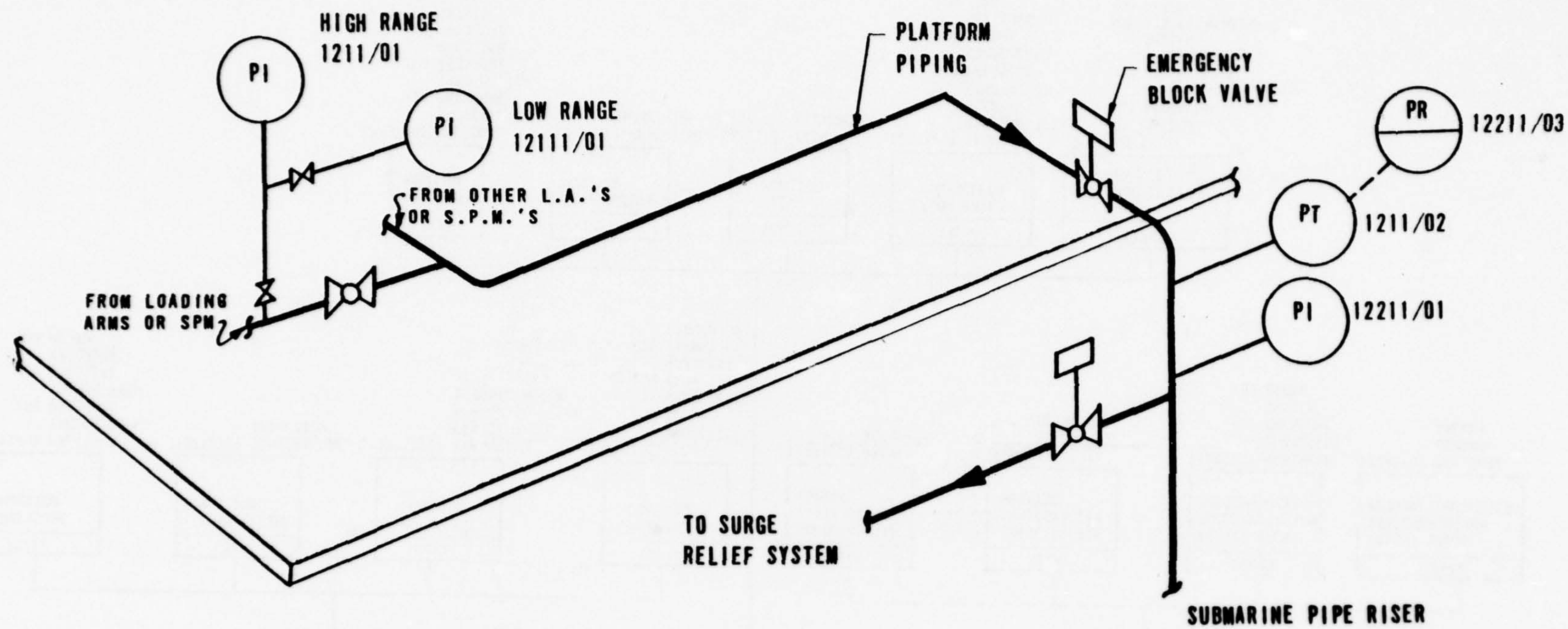


FIGURE 2-14, PRESSURE MEASUREMENT (12211)

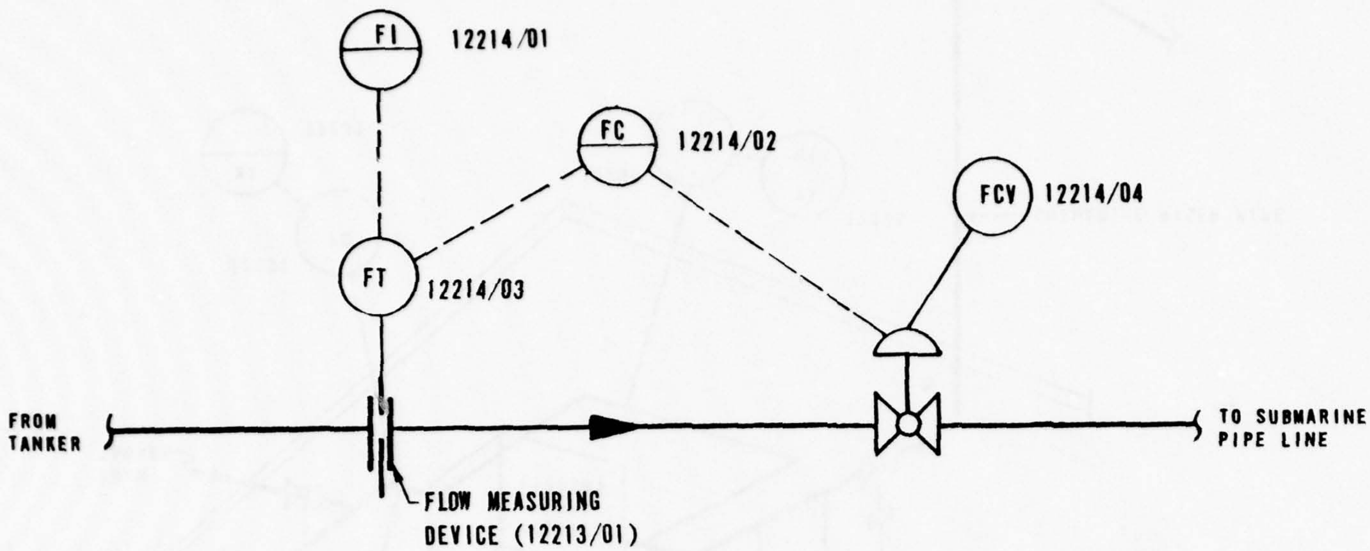


FIGURE 2-15, FLOW CONTROL (12213 & 12214)

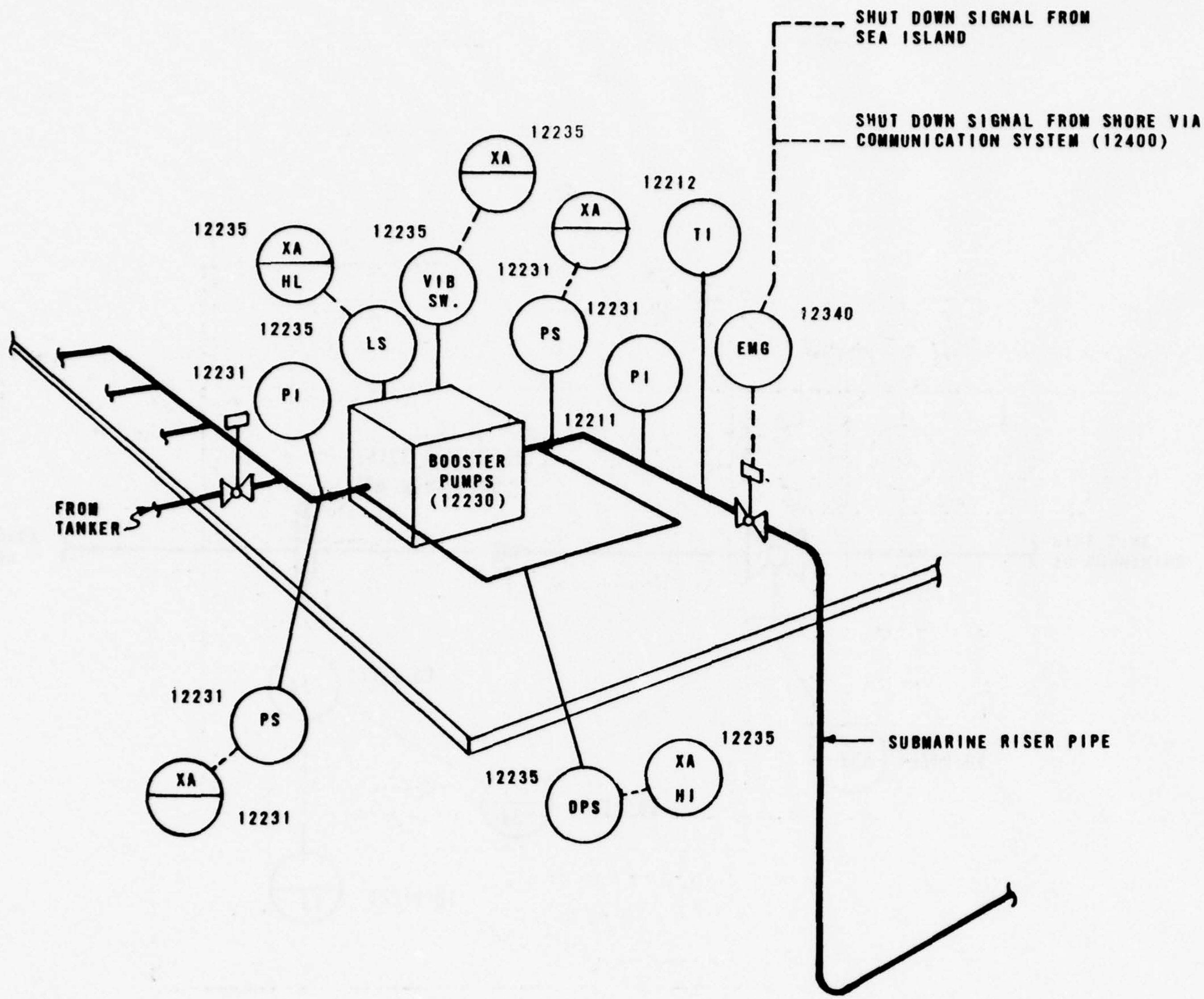


FIGURE 2-16, BASIC PLATFORM WITH BOOSTER PUMPS (12200)

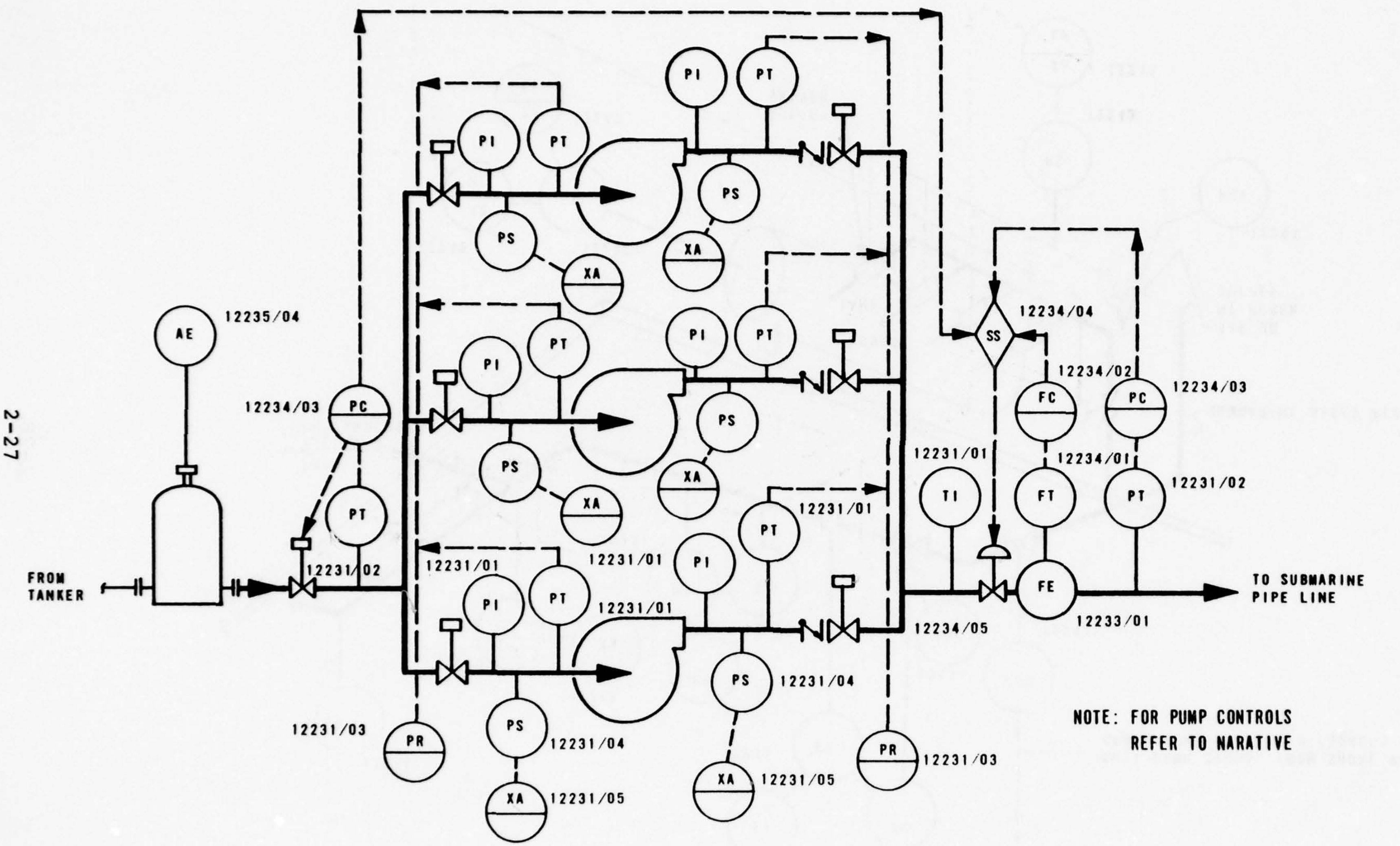


FIGURE 2-17, BOOSTER PUMPS CONTROLS (12230)

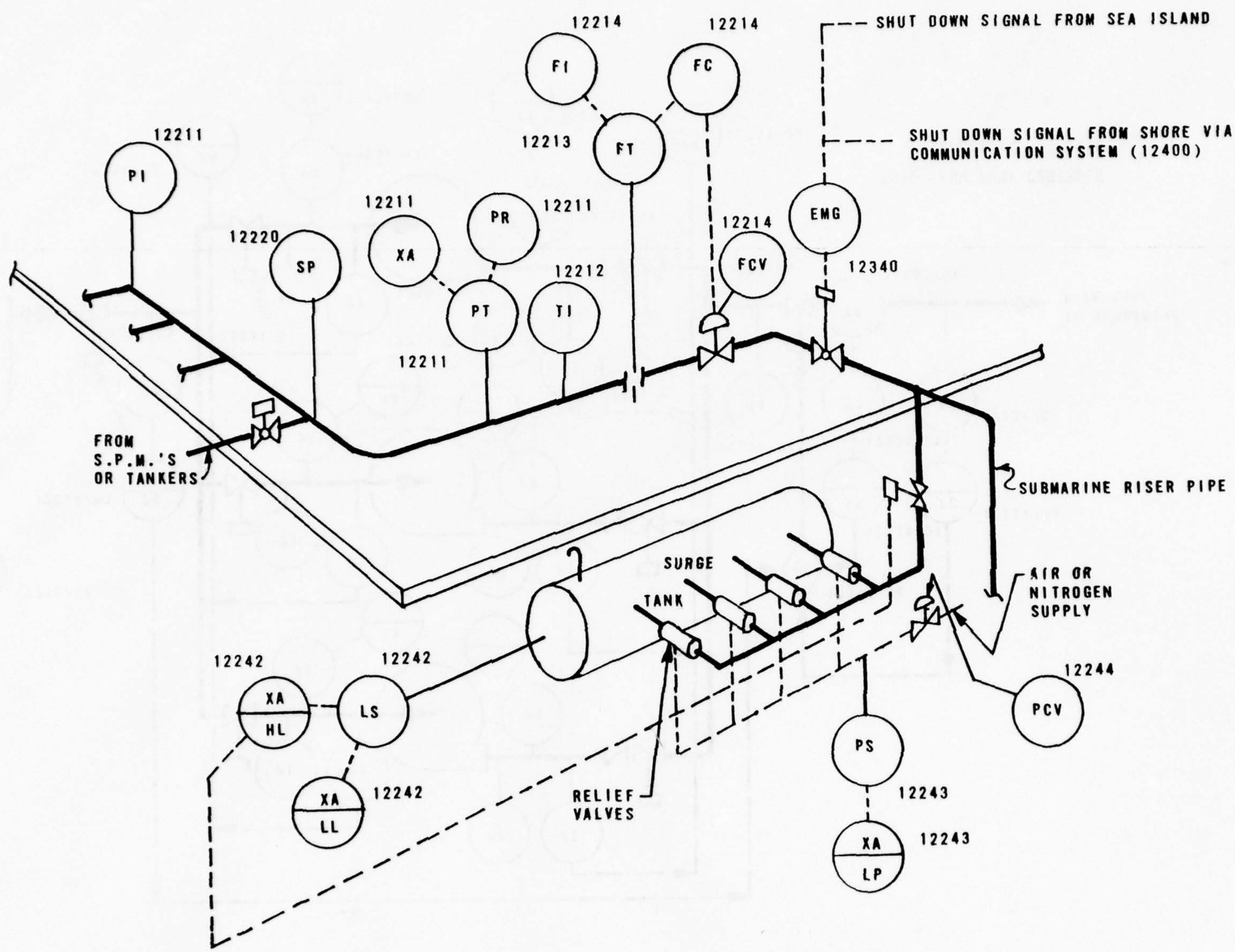


FIGURE 2-18, BASIC PLATFORM WITH SURGE PROTECTION (12240)

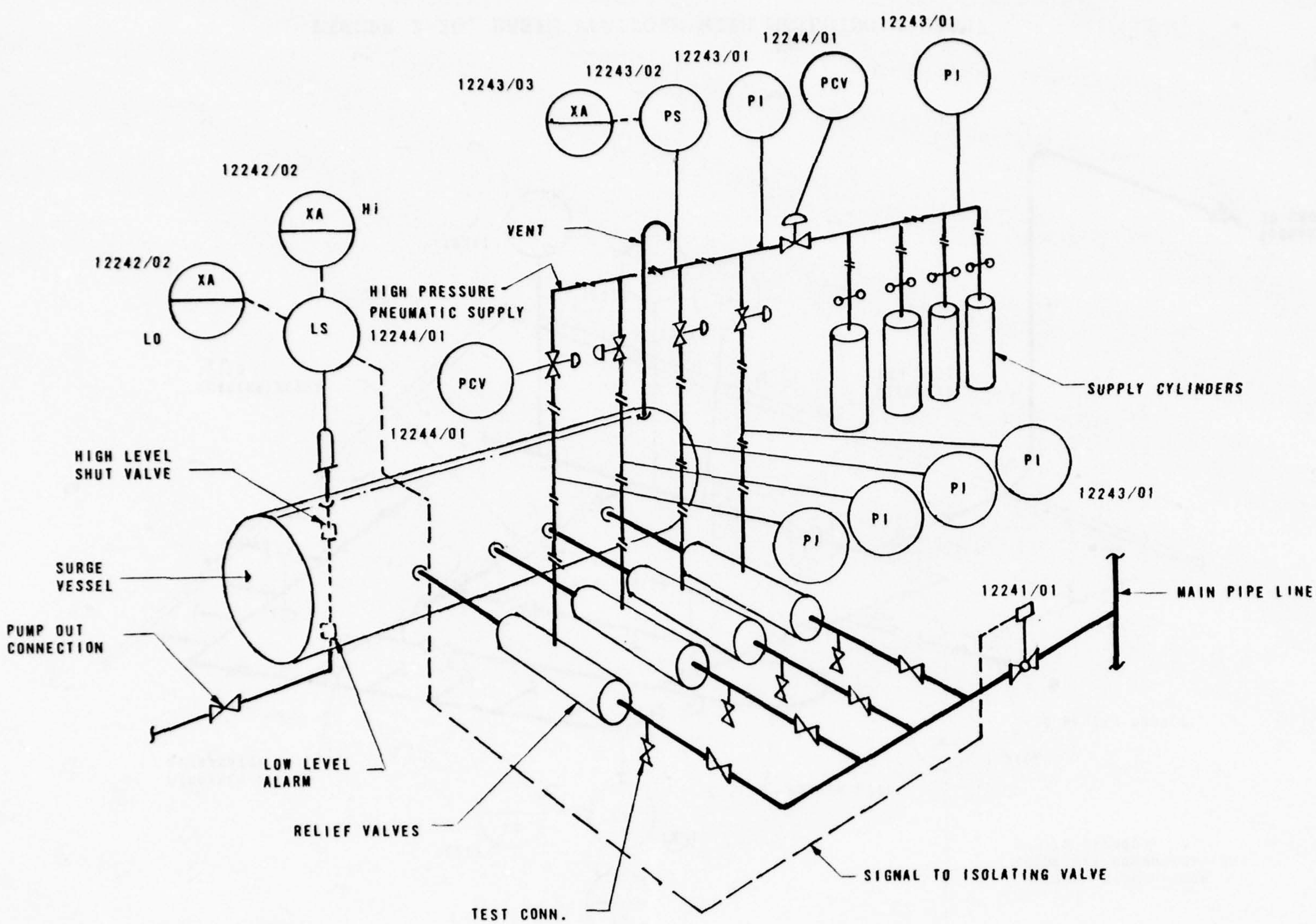


FIGURE 2-19, SURGE RELIEF SYSTEM (12240)

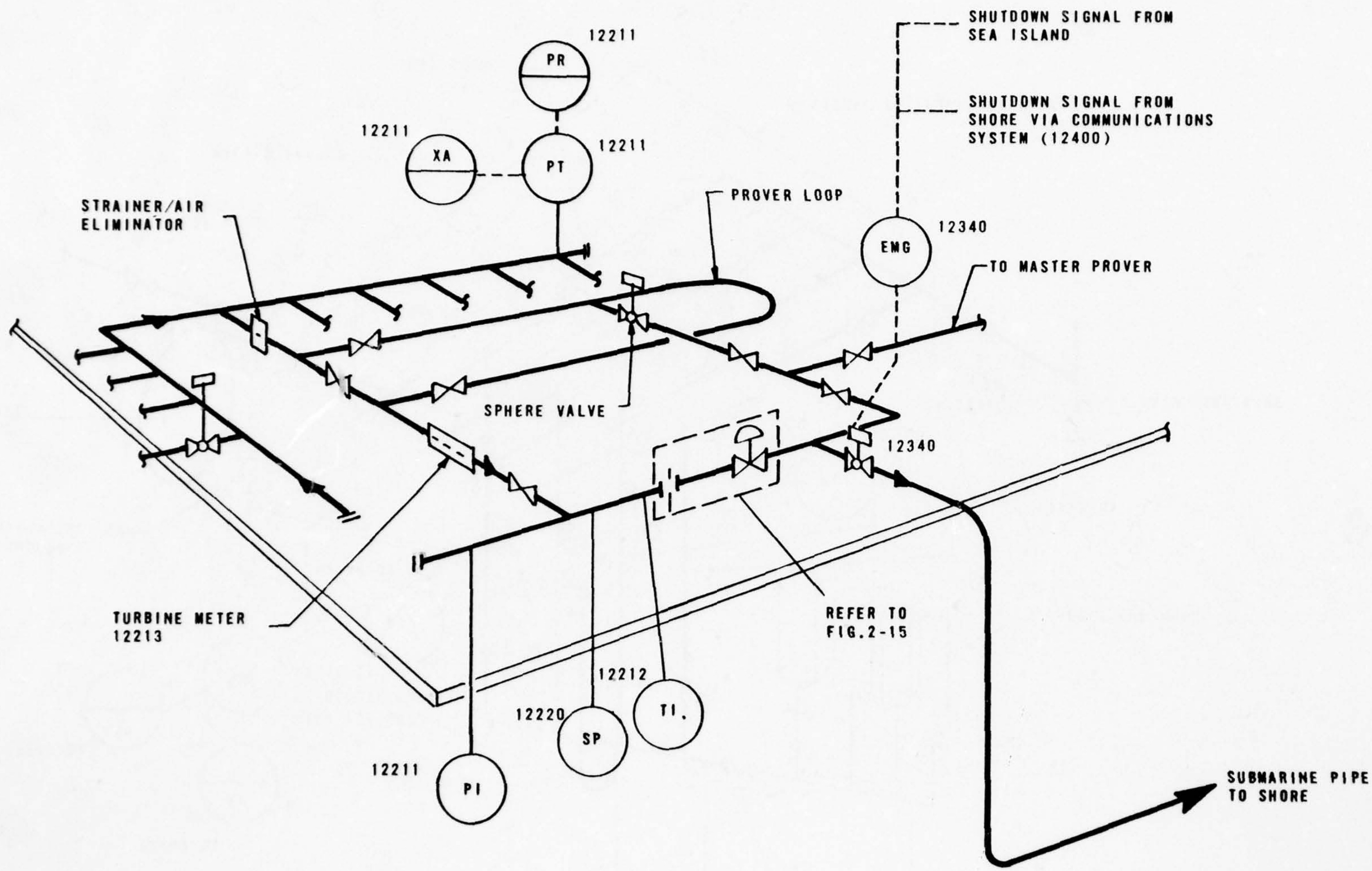


FIGURE 2-20, BASIC PLATFORM WITH METERING (12200)

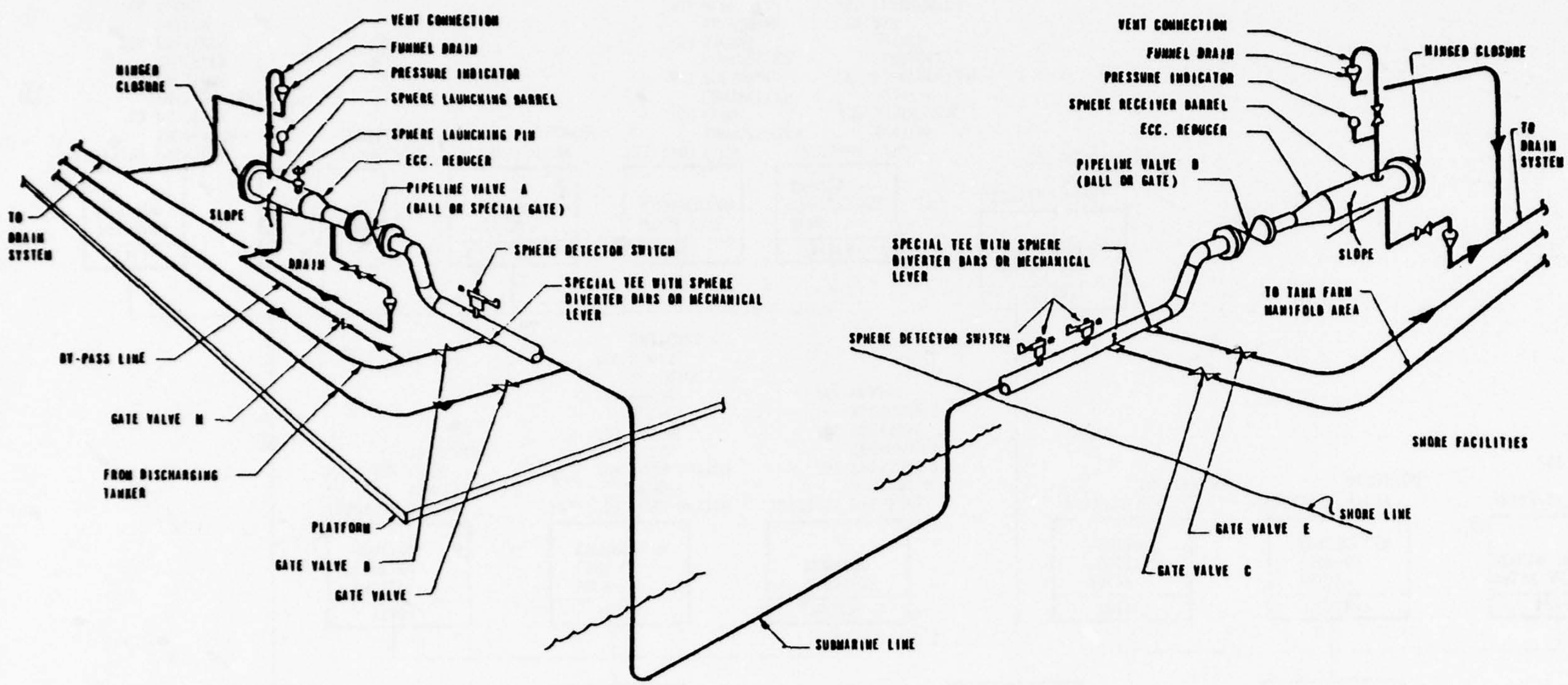


FIGURE 2-21, PIGGING ARRANGEMENT DIAGRAM

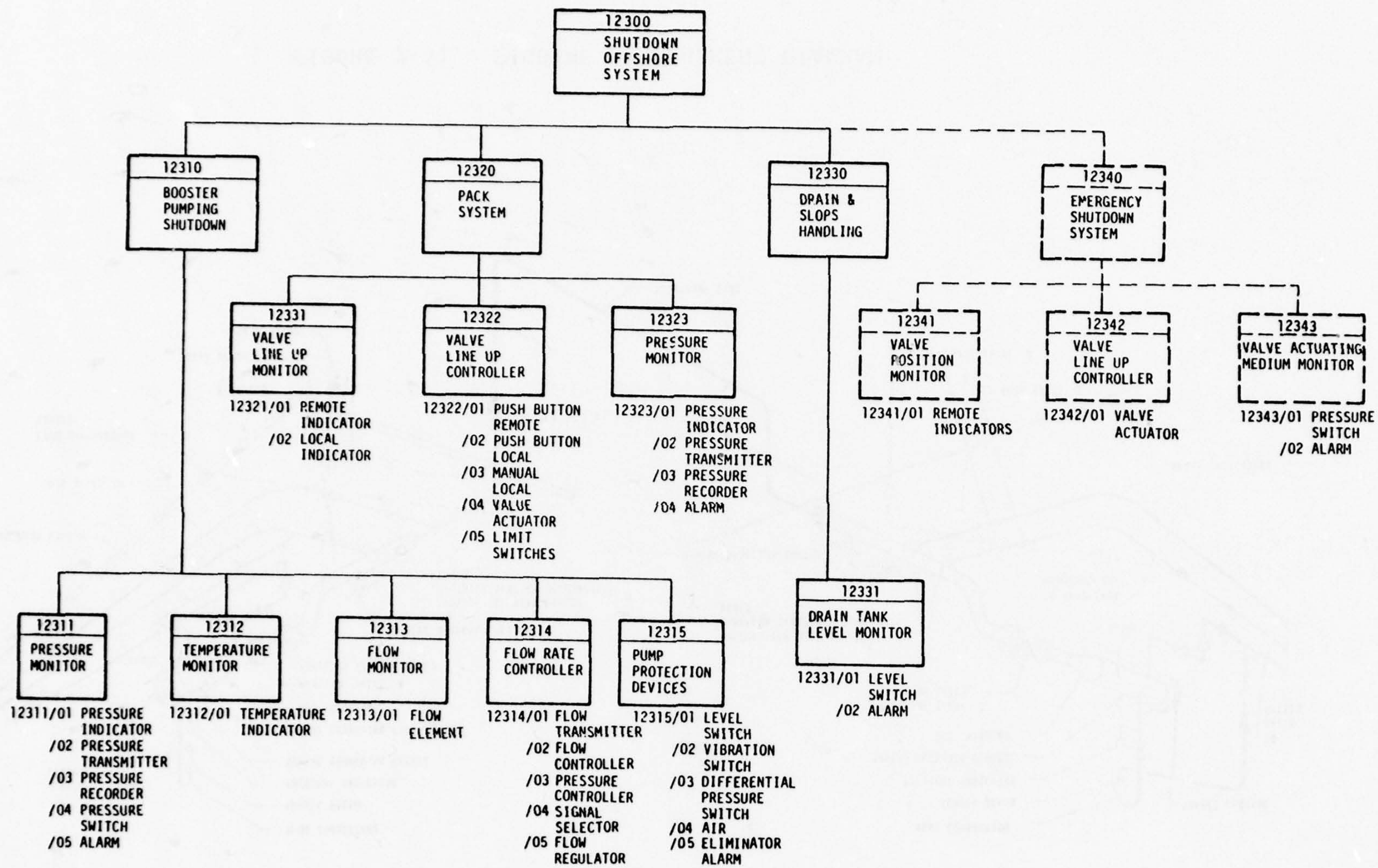


FIGURE 2-22, SHUTDOWN OFFSHORE SYSTEM - 12300 ESD

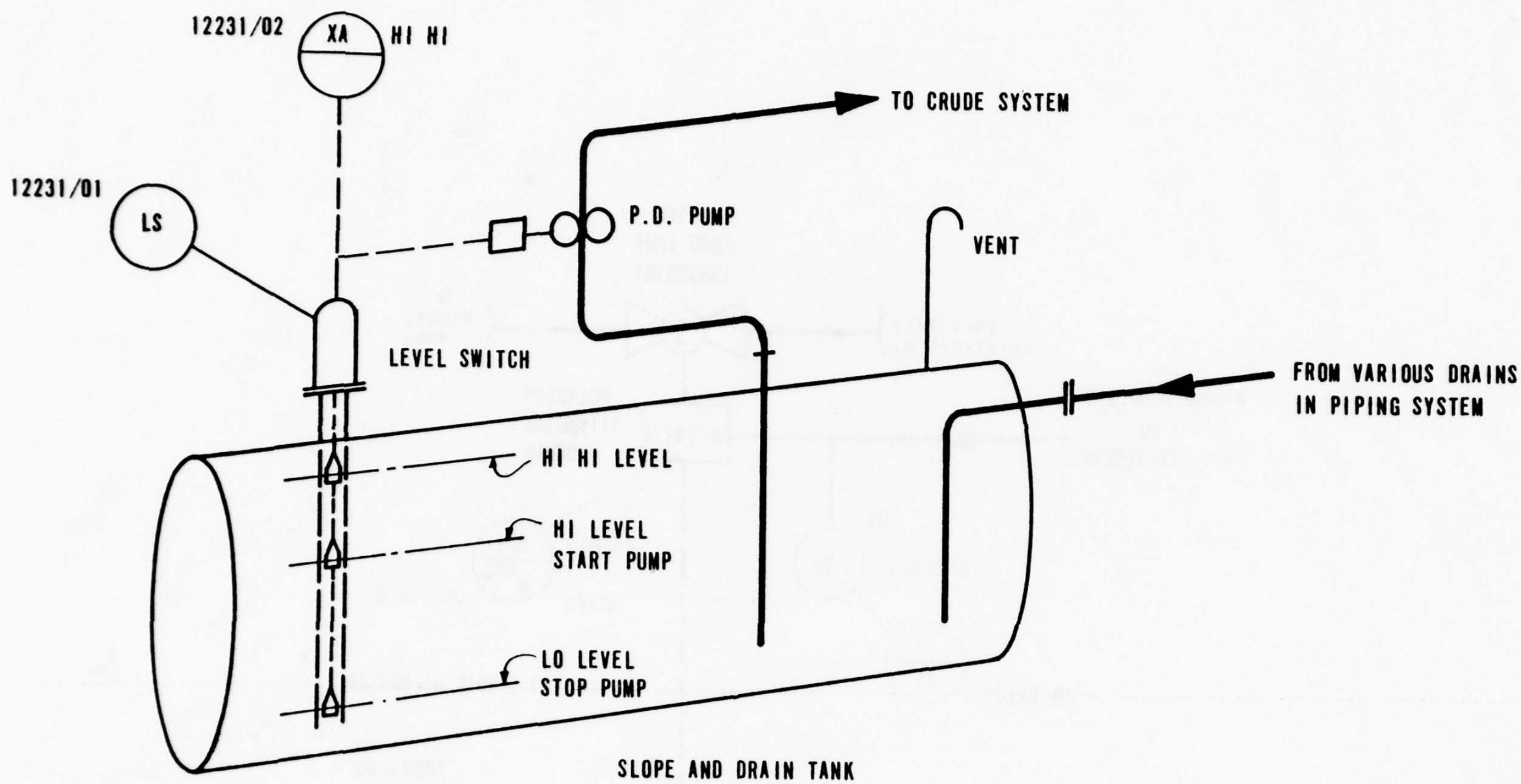


FIGURE 2-23, DRAIN AND SLOP SYSTEM (12330)

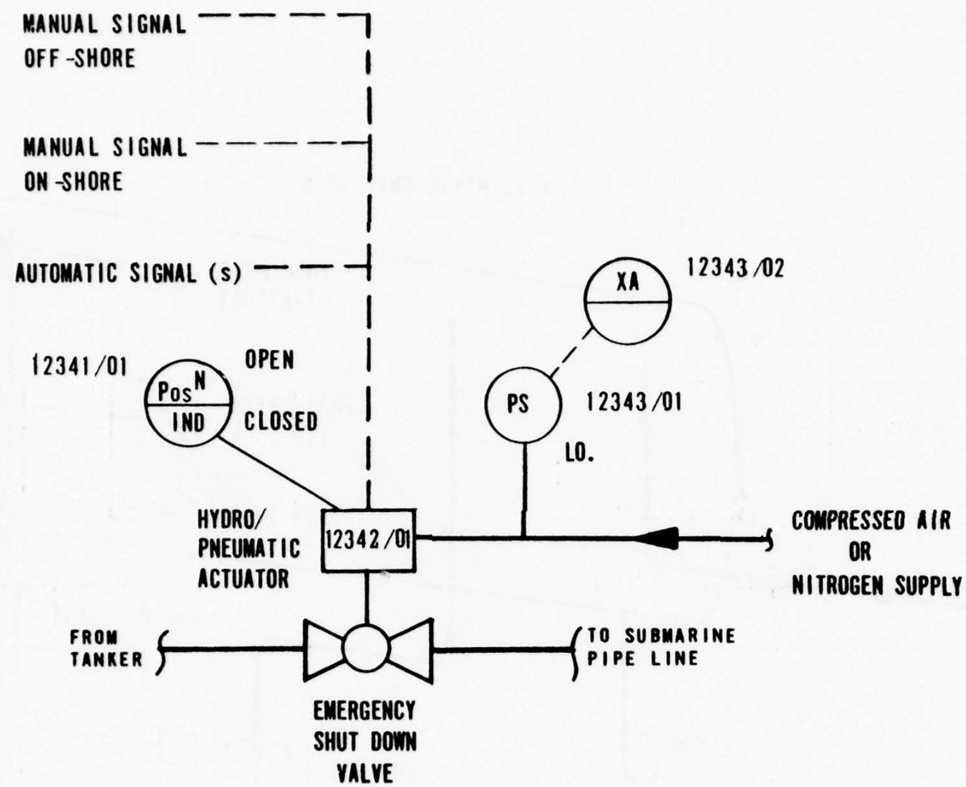


FIGURE 2-24, EMERGENCY SHUTDOWN SYSTEM (12340)

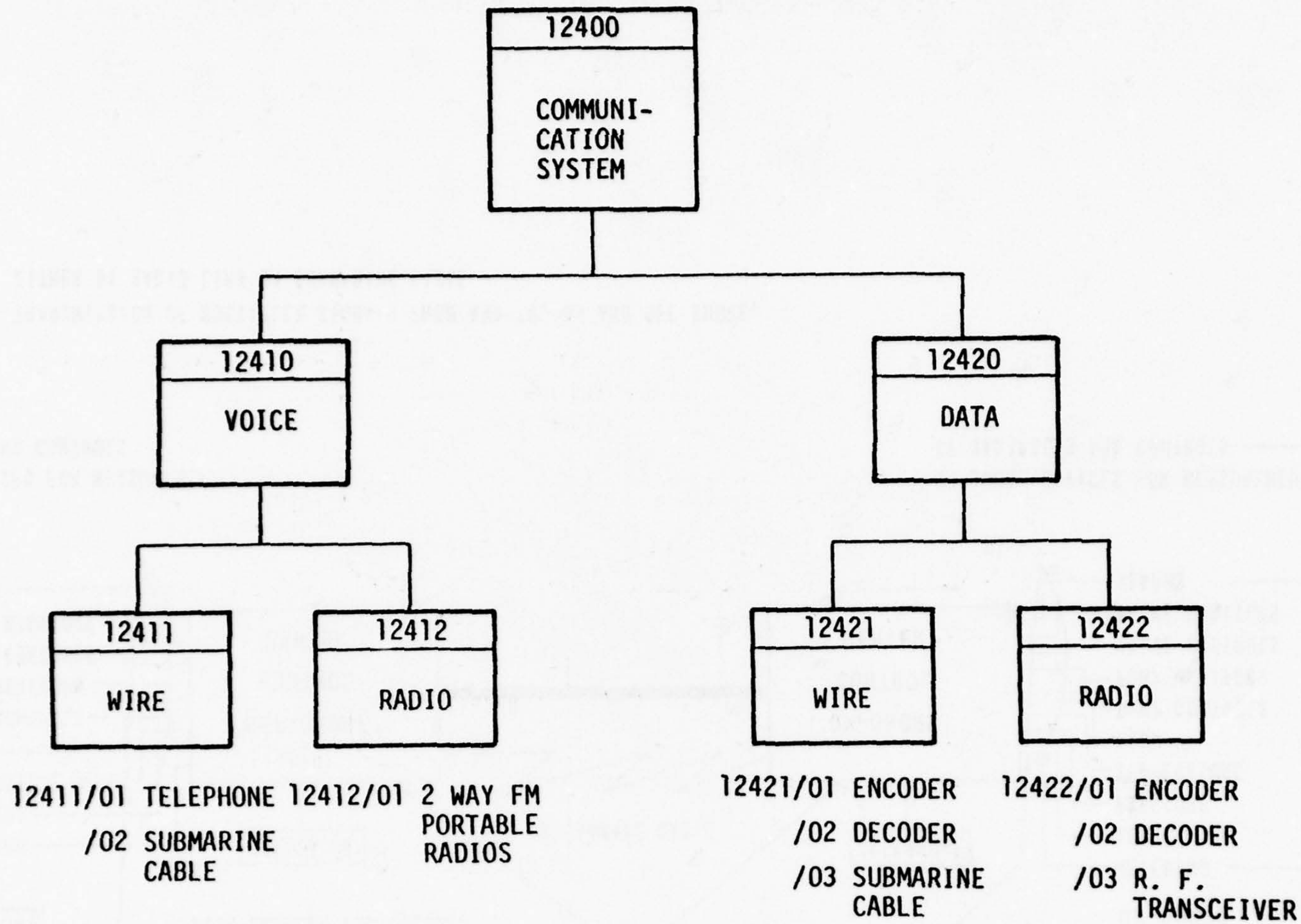
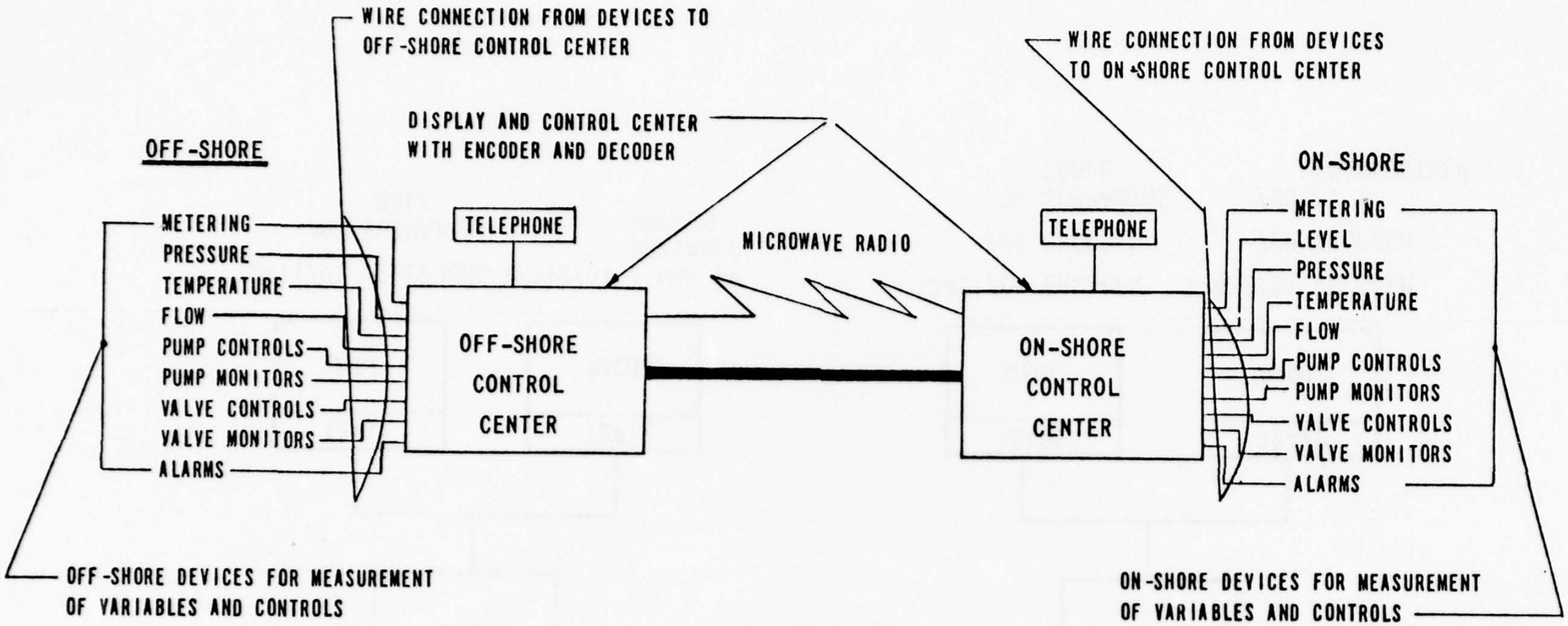
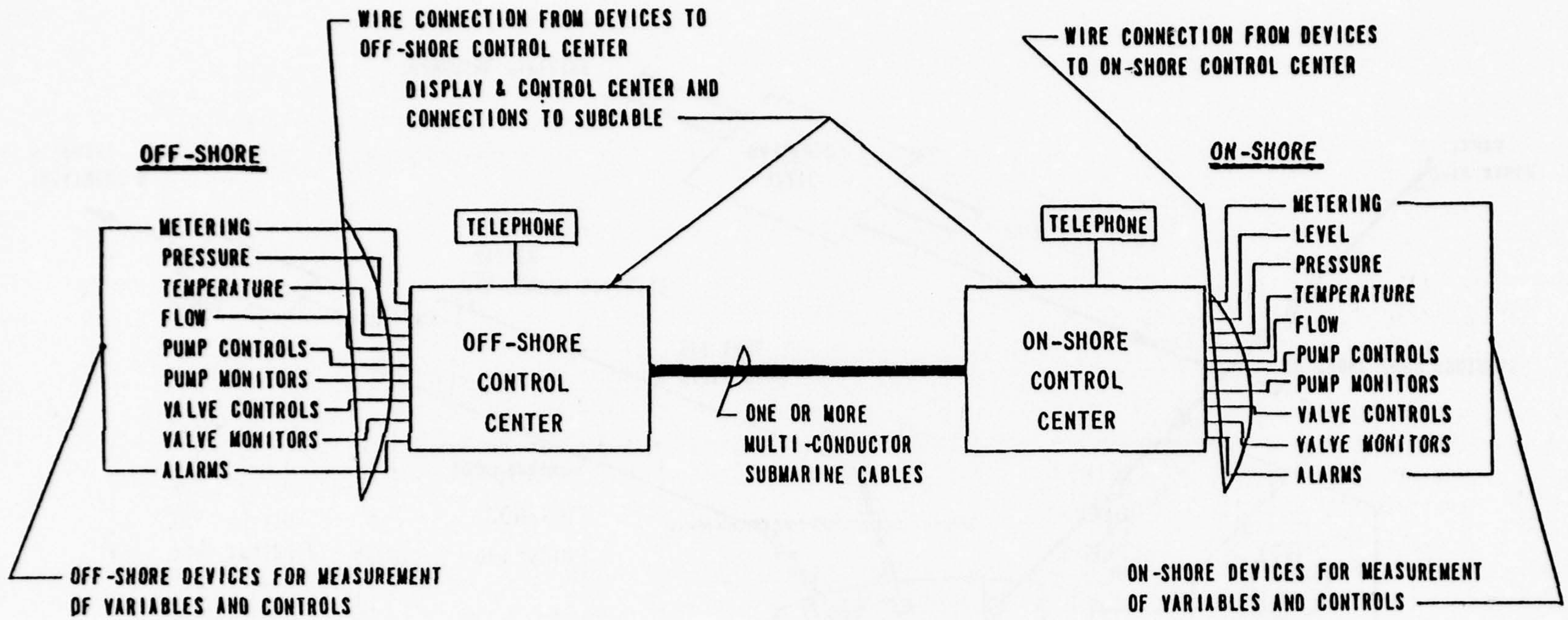


FIGURE 2-25, COMMUNICATIONS SYSTEM - 12400 ESD



NOTE; TRANSMISSION OF MULTIPLEX SIGNALS FROM AND TO, ON AND OFF SHORE, EITHER BY RADIO LINK OR SUBMARINE CABLE.

FIGURE 2-26, COMMUNICATION MULTIPLEX (12400)



NOTE: TRANSMISSION OF SIGNALS FROM & TO ON-SHORE AND OFF-SHORE, EACH CONDUCTOR IS DEDICATED TO ONE FUNCTION ONLY

FIGURE 2-27, COMMUNICATIONS DIRECT WIRE (12400)

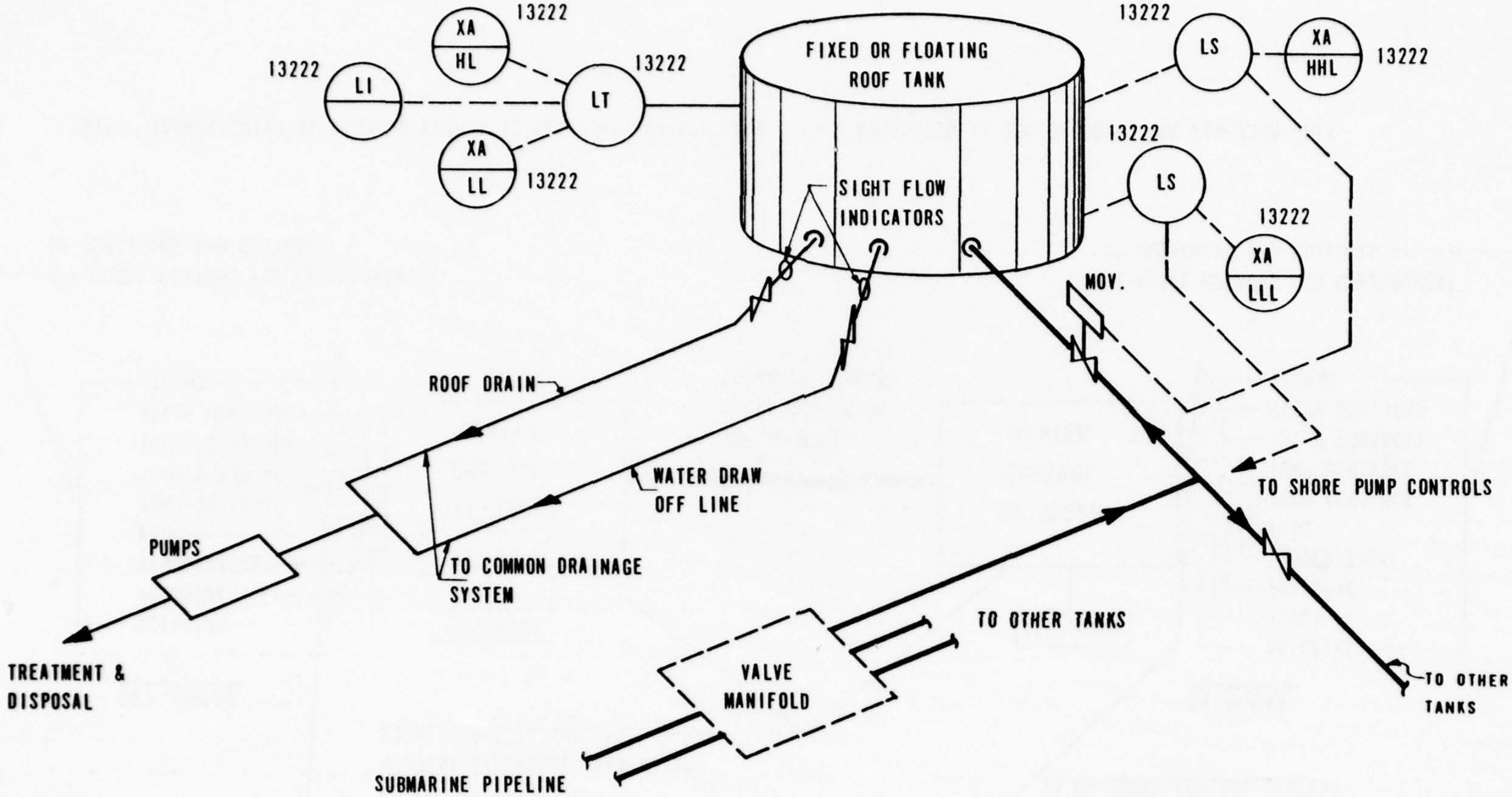


FIGURE 2-28, BASIC ON-SHORE FACILITIES (13000)

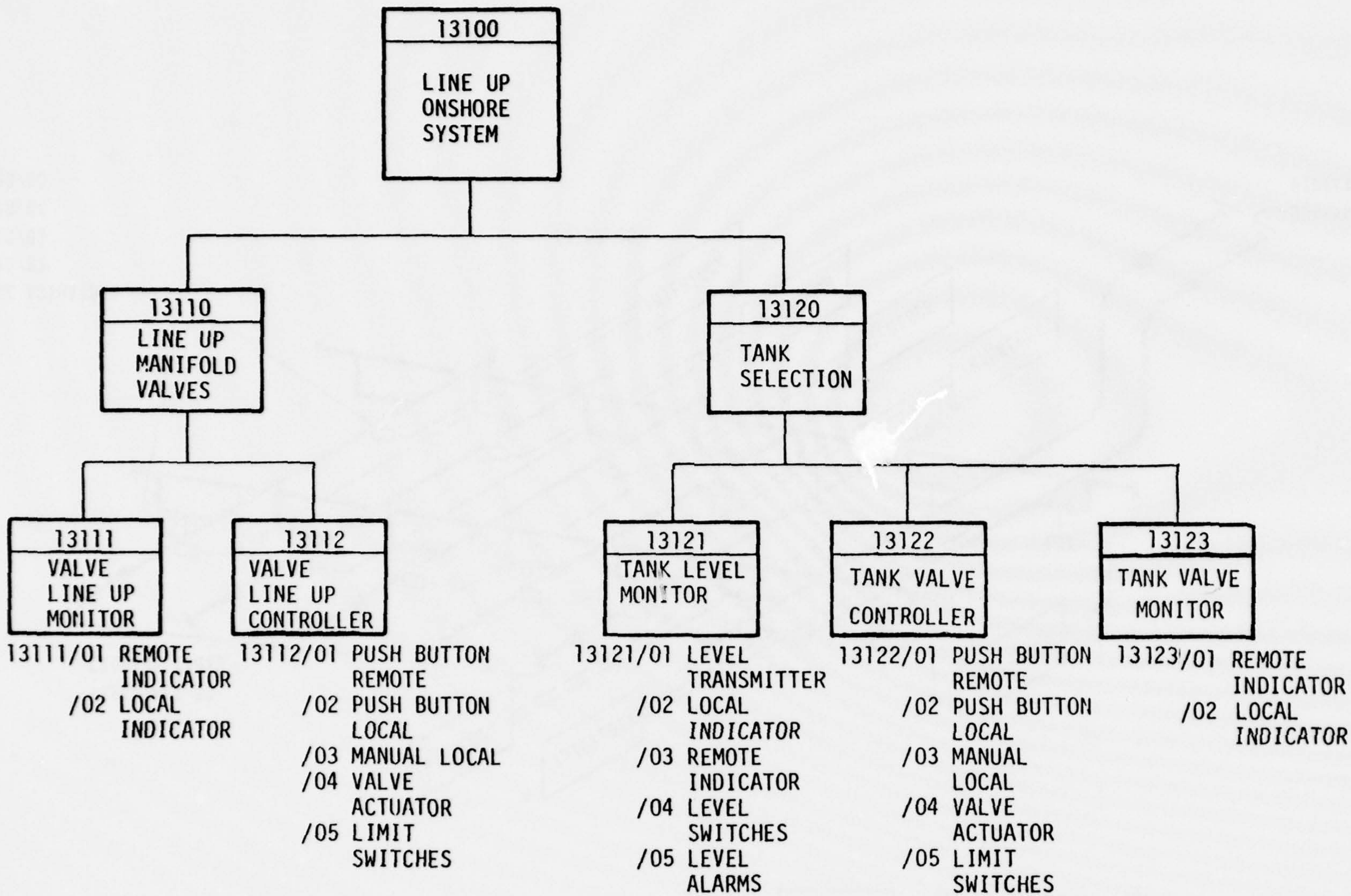


FIGURE 2-29, LINE-UP ONSHORE SYSTEM - 13100 ESD

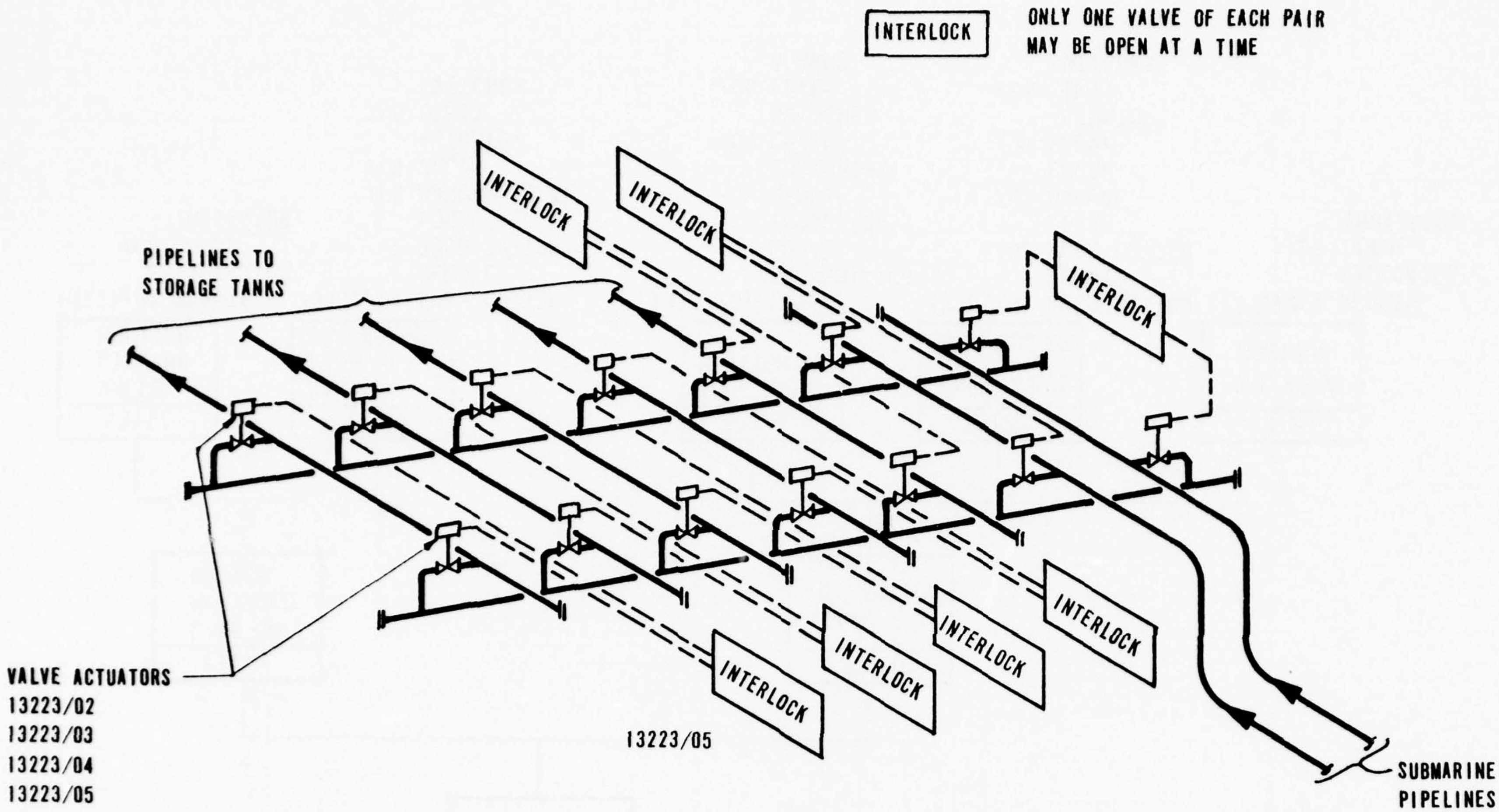
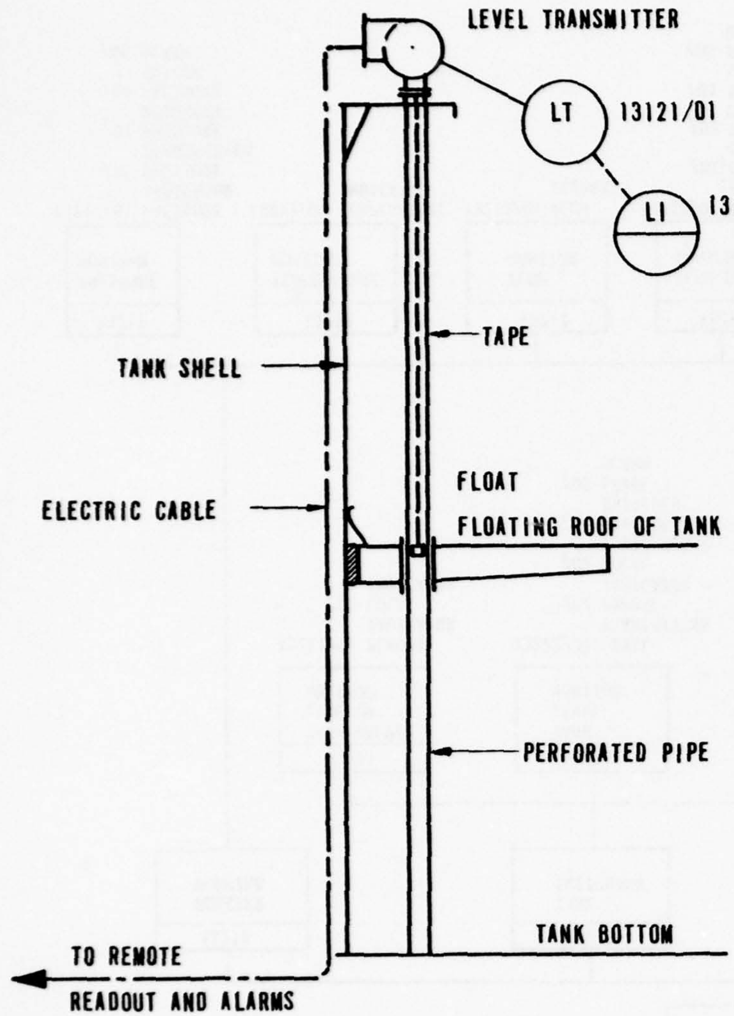
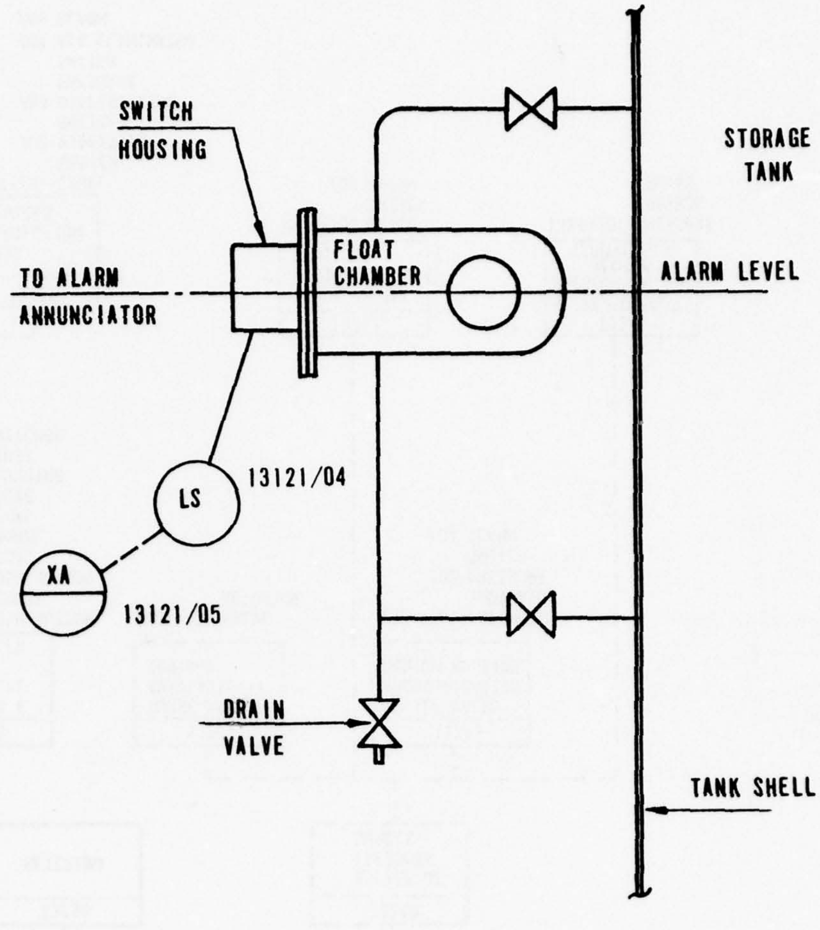


FIGURE 2-30, ONSHORE VALVE MANIFOLD (13110)



LEVEL MONITORING FOR CONTINUOUS READOUT OR CONTROL



LEVEL ALARM SWITCH

FIGURE 2-31, ONSHORE TANK LEVEL MEASUREMENT (13121)

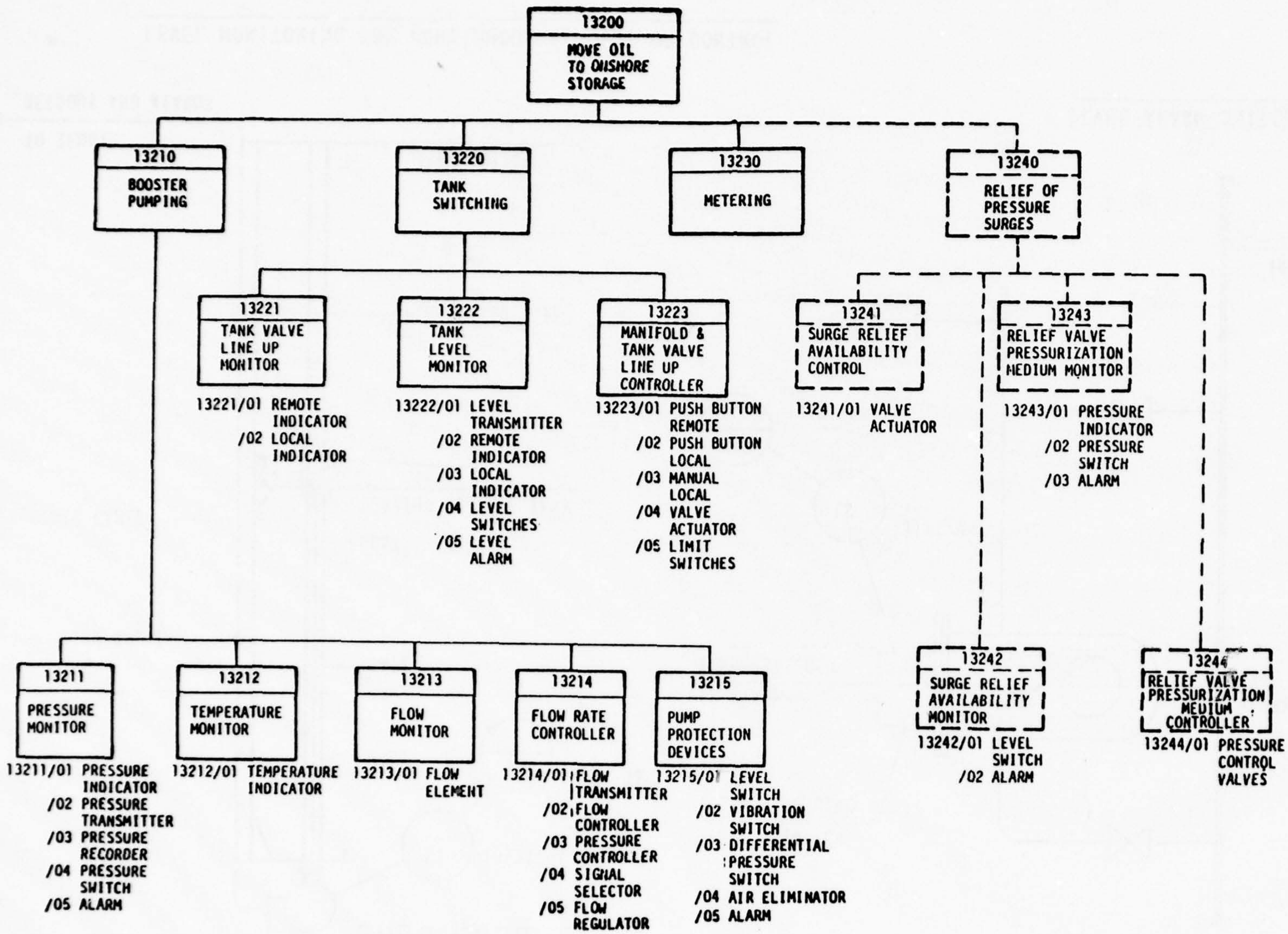


FIGURE 2-32, MOVE OIL TO ONSHORE STORAGE - 13200 ESD

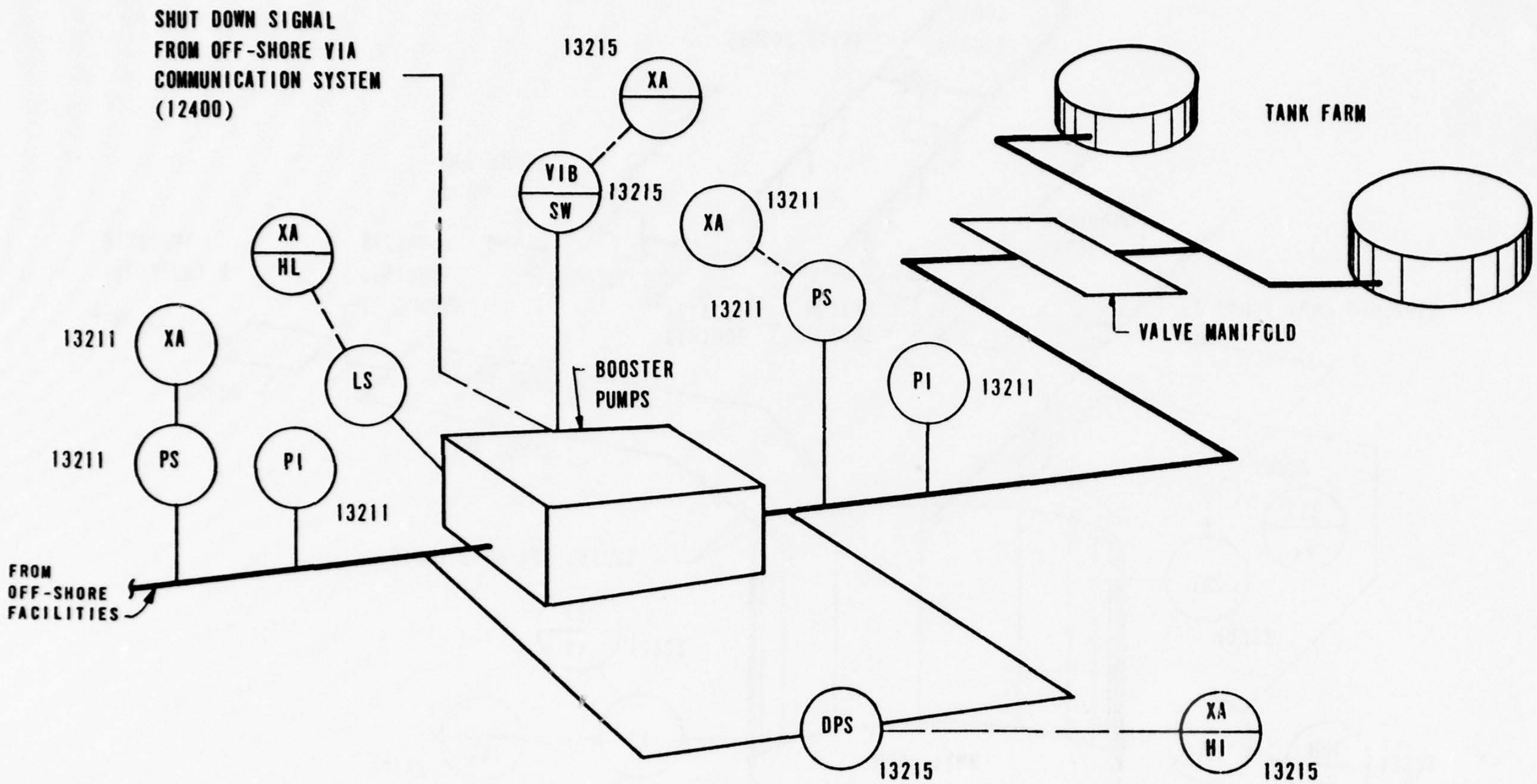


FIGURE 2-33, BASIC ONSHORE FACILITIES WITH BOOSTER PUMPS (13200)

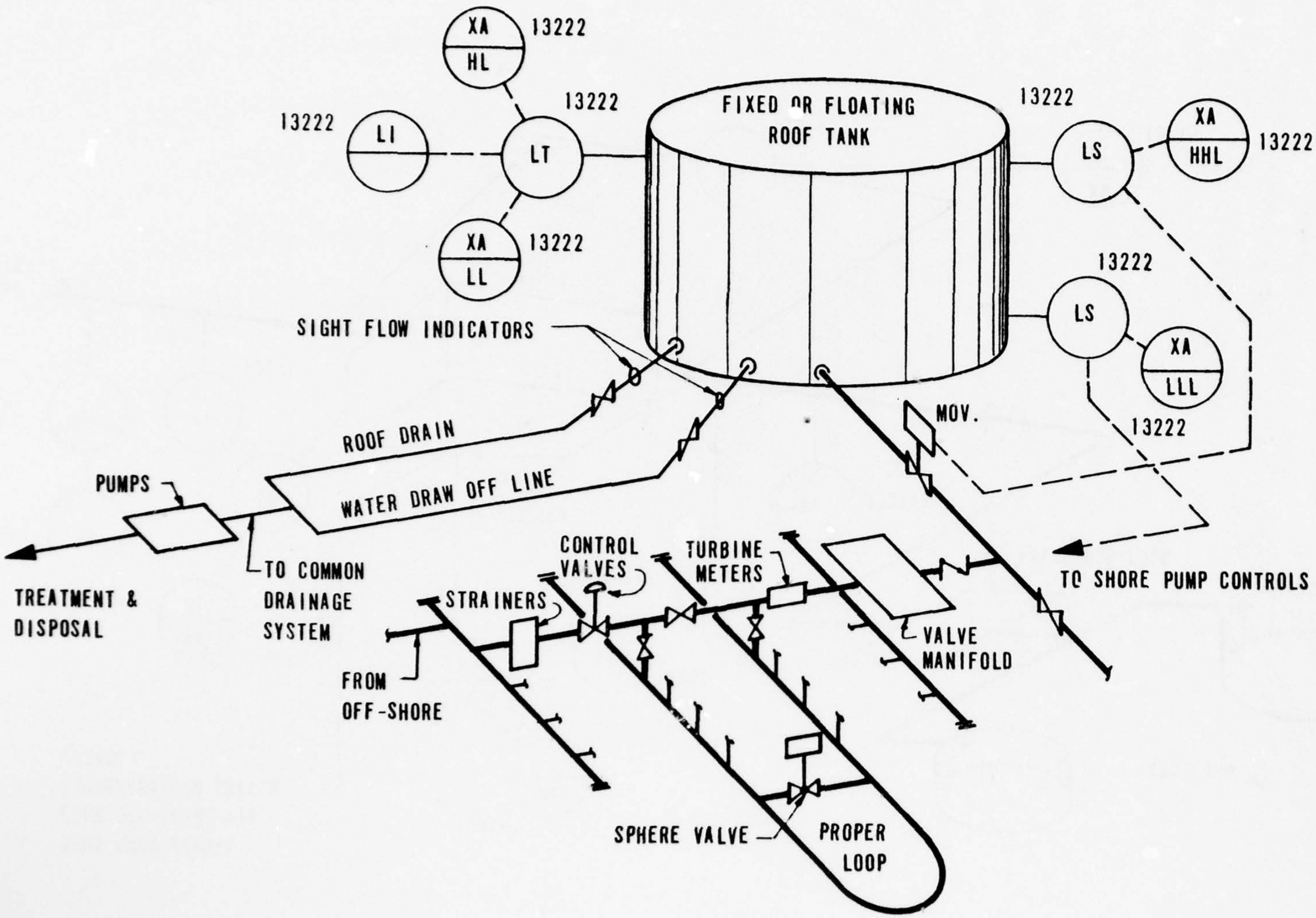


FIGURE 2-34, BASIC ONSHORE FACILITIES WITH METERING (13200)

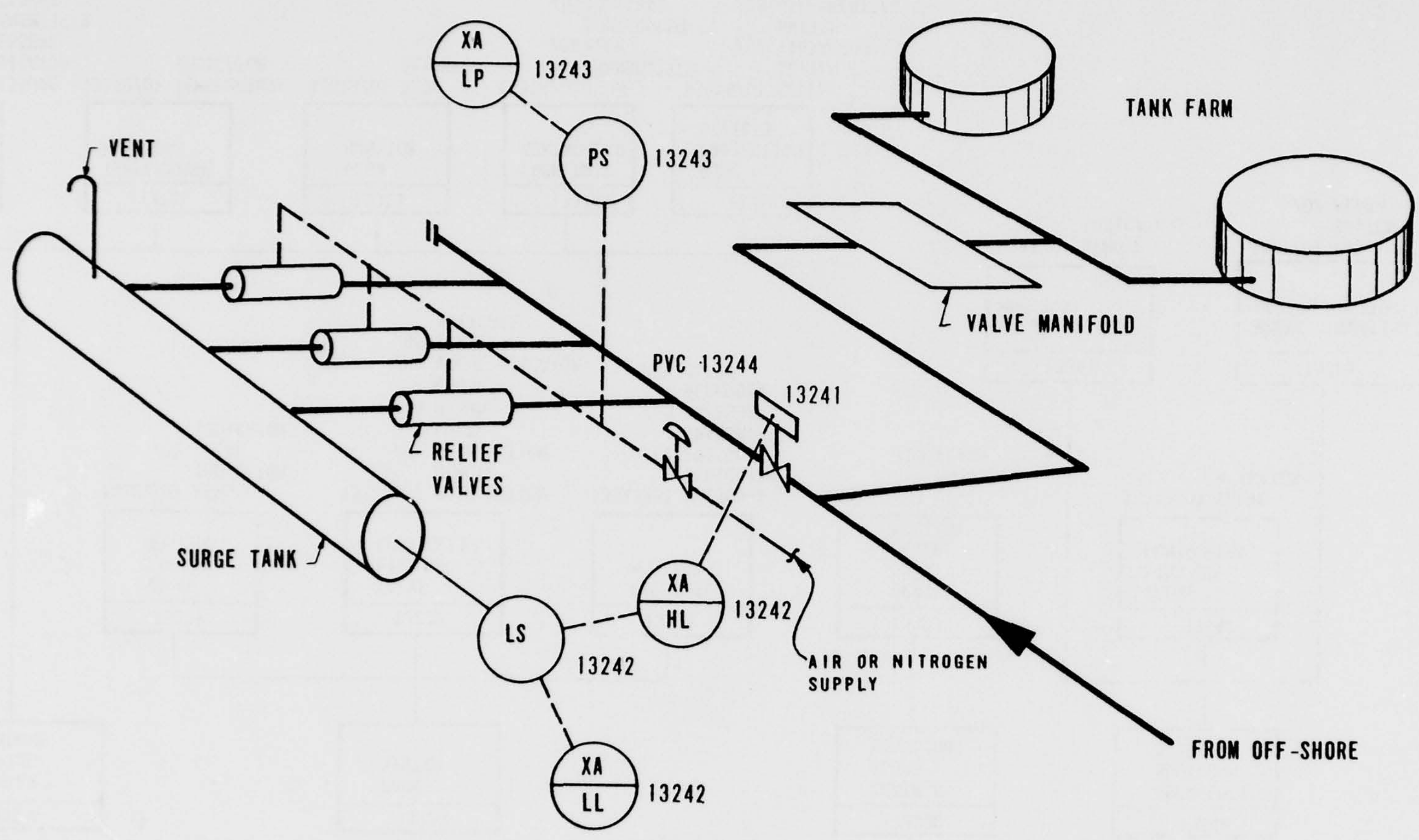


FIGURE 2-35, BASIC ONSHORE FACILITIES WITH SURGE PROTECTION (13200)

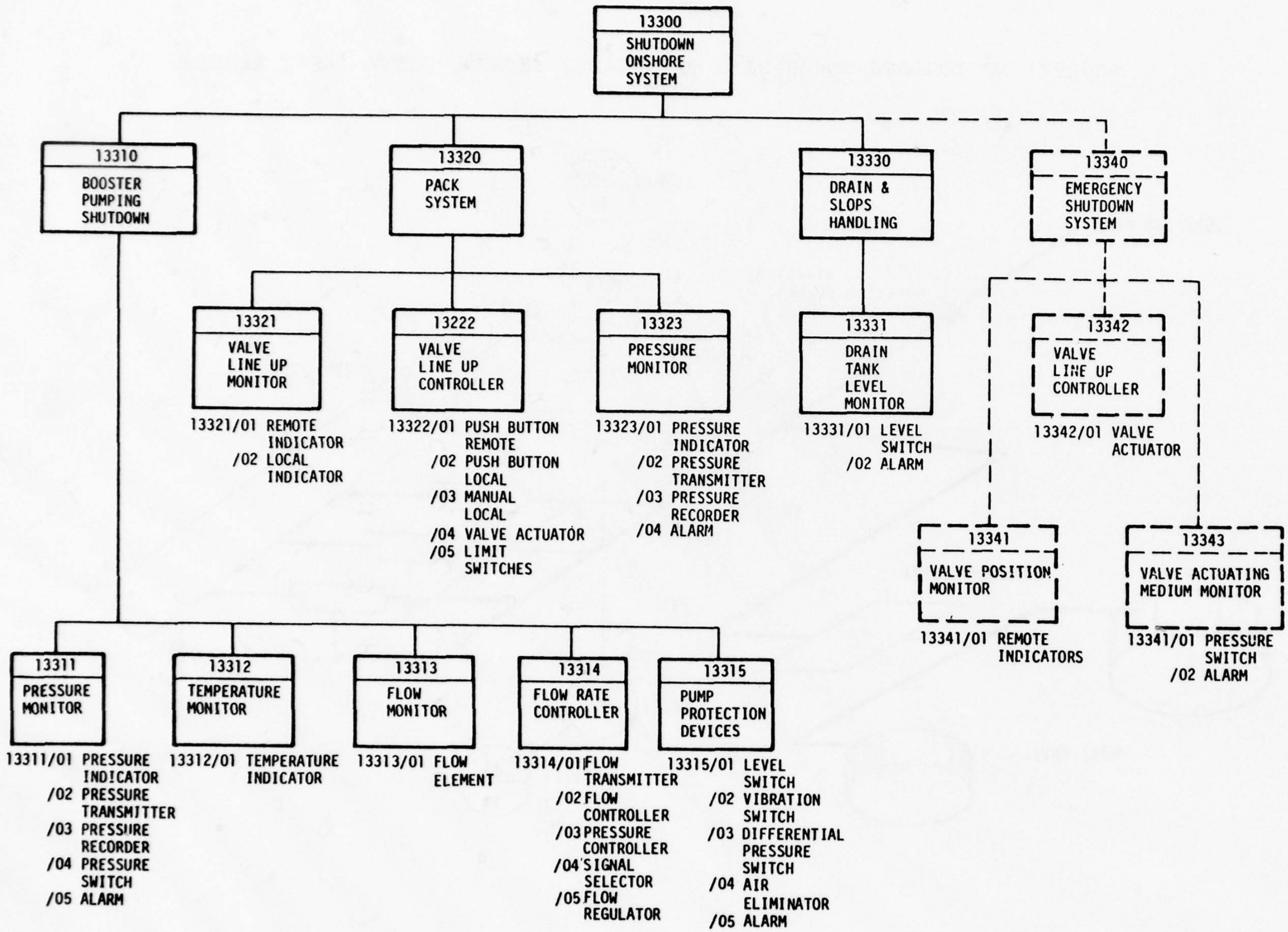


FIGURE 2-36, SHUTDOWN ONSHORE SYSTEM - 13300 ESD

3.0

NUMERICAL RATING SYSTEM

3.0
NUMERICAL RATING SYSTEM

3.1 INTRODUCTION

In any rating system, there exists a blend of subjective judgment and objective performance. Rating systems which crank out a single number lack "real world" assumptions, and decisions based purely on "experience" lack completely objective information. Ideally, decisions or ranking of selections should be made with all information being objective. However, this is not always possible.

The system described here is one which utilizes the objective reliability and failure effects data and tempers it with the professional judgment of the design reviewer. This is the philosophy that flows through this entire document. Probabilities of failure, spill risks, fault trees, etc., are presented, but so also are discussions of applicability, design criteria, applied engineering principles, and actual operating experience.

This section is an extension of the previous sections - the design reviewer will draw upon the concepts and criteria presented in them to describe the system he is evaluating and to numerically rate this proposed system against a benchmark system. In order to do this, the functional to equipment structuring of the Equipment Staging Diagram must be consolidated to a purely equipment/element oriented network. Table 3-1 depicts this network through the element level. Table 3-2 maps the consolidated network to the ESD. For definition purposes, an element is a functional grouping of equipments.

TABLE 3-1. DWP ELEMENT HIERARCHY

- DWP
  - TANKER
    - Pumps
    - Valves
    - Tanks
    - Piping
    - Emergency Shutdown System
    - Communications
  - OFFSHORE FACILITIES
    - Piping
    - Valves
    - Sampling
    - Booster Pumps
    - Surge Relief System
    - Drain and Slops System
    - Emergency Shutdown System
    - Communications
  - ONSHORE FACILITIES
    - Valves
    - Tanks
    - Booster Pumps
    - Surge Relief System
    - Drain and Slops System
    - Emergency Shutdown System

TABLE 3-2. ESD TO ELEMENT MAP

	PIPING	PUMPS	VALVES	TANKS	SAMPLERS	SURGE RELIEF	DRAIN SLOPS	EMERGENCY SHUTDOWN	COMMUNICATIONS	NOT APPLICABLE
TANKER										
11110			•							
11210		•								
11220			•	•						
11310		•								
11320	•									
11330								•		
11340			•							
11410									•	
11420									•	
OFFSHORE										
12110	•									
12120			•							
12210	•									
12220					•					
12230		•								
12240						•				
12250										•
12260										•
12310		•								
12320			•							
12330							•			
12340								•		
12410									•	
12420									•	
ONSHORE										
13110			•							
13120				•						
13210		•								
13220			•	•						
13230										•
13240						•				
13310		•								
13320	•		•							
13330							•			
13340								•		
13410									•	
13420									•	

3.2 DESIGN ADEQUACY

The design adequacy is the measure of the suitability of a Deepwater Port to perform its functions safely. It is intended to serve as a guideline in the review of any DWP. The evaluation of any proposed DWP should include an examination of the plans of the facility to insure that the proper amount of control equipment is installed. Otherwise, a lack of certain control equipment could result in a higher probability of failure, and a greater risk of an oil spill.

A checklist has been developed to serve as a guideline in the evaluation of the control system design of any proposed DWP. First, it is important that all pertinent design material be gathered. This includes studying preliminary schematics, design drawings, equipment lists, and direct feedback from the DWP applicants.

A considerable amount of time can be spent in searching through the preliminary design material for those pieces of equipment that operate as a control function, and secondly, determining the exact number of like equipment. In this report, descriptions of DWP control equipment include design criteria, catalog cuts, reliability, effects of failure, spill risk, procedural alternatives, and maintenance information. A general understanding of DWP control equipment can be gained by reading Section 2.0 and Appendix E.

In an effort to preserve procedural clarity, one element in the DWP control system is provided as an example. The element is the Offshore Surge Relief System, as taken from Table 3-1. The following is the step-by-step procedure upon which all control elements of a DWP should be evaluated.

Step 1 - Gather and study all available preliminary design material for the proposed element.

This includes the examination of drawings, equipment lists, and applicant sources. The material written in Section 2.0 and Appendix E on DWP equipment should also be reviewed.

Step 2 - Construct a Design Adequacy Checklist.

This list should include all equipment considered essential in controlling the transfer of oil in Deepwater Ports. The design reviewer can use the ESD's of Section 2.0 to construct a checklist for all or part of the system in question.

Step 3 - Compare proposed element equipment against those presented in the Design Adequacy Checklist.

The typed portion of Table 3-3 is constructed from Figure 2-13. (Scanning the related figure will acquaint the reviewer with the Offshore Surge Relief Equipment usually found on a typical DWP.) By comparing the checklist with the material gathered in step number one, it is possible to see if the proposed element has an adequate amount of control equipment. It may have extra pieces of equipment, and these should be entered under the element heading. Each piece of proposed control equipment is checked against the typical DWP equipment list as shown in Table 3-3. In an actual review, the handwritten information in Table 3-3 would be extracted from a DWP applicant's proposed design and compared with the Design Adequacy Checklist.

TABLE 3-3. DESIGN ADEQUACY CHECKLIST

OFFSHORE

DWP Oil Port I EVALUATOR J. Mandato

	EQUIPMENT	✓	COMMENTS
• **SURGE RELIEF SYSTEM** 12240			
12241	SURGE RELIEF AVAILABILITY CONTROL		
	Valve Actuator 12241/01	✓	One valve actuator
12242	SURGE RELIEF AVAILABILITY MONITOR		
	Level Switch 12242/01	✓	One LS.
	Alarm - High 12242/02	✓	One XA-high
	Alarm - Low 12242/03	✓	One XA-low
12243	RELIEF VALVE PRESSURIZATION MEDIUM MONITOR		
	Pressure Indicator 12243/01	✓	Six PI in series

TABLE 3-3. DESIGN ADEQUACY CHECKLIST
(Continued)

OFFSHORE

DWP Oil Port I EVALUATOR J. Mandato

	EQUIPMENT	✓	COMMENTS
	Pressure Switch 12243/02	✓	One P.S
	Alarm - Low 12243/03	✓	One XA-low
12244	RELIEF VALVE PRESSURIZATION MEDIUM CONTROLLER		
	Pressure Control Valves 12244/01	✓	Five PCV in series

3.3 RELIABILITY/FAILURE EFFECTS RATING

Once the design reviewer determines that a complete control system is proposed, through the use of the Design Adequacy Procedure described above, the system can then be rated numerically.

Figure 3-1 contains the fault tree for the Surge Relief System. Appendix B contains the fault trees for all of the individual elements of the oil transfer control system identified in Table 3-1. These fault trees will be needed in the execution of the numerical rating system. Additionally, Appendix B gives the reader background information on fault tree methodology.

3.3.2 NUMERICAL RATING SYSTEM PROCEDURE

The rating system is structured around the combination of a Reliability rating and a Failure Effects rating. These ratings will enable the professional design reviewer to make an informed decision on the acceptability of the applicant's design. The procedure builds upon previous sections in this report and is accomplished in five major steps. These steps are presented in this section and their use is illustrated in the continuation of the example of the Surge Relief System.

Step 1 - Fill out an Element Reliability/Effects rating sheet for each element in the proposed system Columns (1-7)

Table 3.4 is an example of the Element Reliability/Effects rating sheet partially filled out for the Offshore Surge Relief System Element.

By walking through the first seven columns of the table as follows, a more complete picture of the numerical rating system can now be realized:

Column (1) should list all equipment found in the particular element. These equipment are readily transcribed from the Design Adequacy Checklist previously constructed.

Column (2) lists the Equipment Probability of Failure which is obtained through the use of the Failure Modes and Effects Analysis (FMEA) Summary in Appendix A. The Probability of Failure is calculated as $(1-e^{-1/MBTF})$, where MBTF is obtained in Appendix C. For large MBTF, on the order of 10,000 barrels or more, the Probability of Failure can be closely approximated by the reciprocal of the MBTF, i.e., $\frac{1}{MBTF}$.

Column (3) lists the benchmark Equipment Probability of Failure which is always 10^{-12}. This probability is assumed to be as close to the perfect piece of equipment as can reasonably be expected.

Column (4) lists the Effects Weighting Factors obtained from Table 3-5, the Effects Weighting Factor Worksheet (taken from Appendix D). This worksheet is filled out for the Surge Relief System identified in this report with space for additional equipment. It should be noted that the weights given to the various effects may be changed by the design reviewer to highlight current concerns for a particular effect. Table 3-6 contains the legend for the various effects categories and the weights given to these effects by the study team.

Column (5) lists the Effects Weighting Factor Fraction which is computed by dividing each individual Effects Weighting Factor in Column (4) by the Sum of the Effects Weighting Factors (ΣFi) (bottom of Column [4]). This procedure normalizes the effects within the element.

Column (6) lists the Effects Weighted Probability of Failure which is calculated by multiplying, for each equipment, the Equipment Probability of Failure (2) by the Effects Weighting Factor Fraction (5).

Column (7) lists the Benchmark Effects Weighted Probability of Failure which is calculated by multiplying, for each equipment, the Benchmark Equipment Probability of Failure (3) by the Effects Weighting Factor Fraction (5).

Step 2 - Calculate the Element Effects Weighted Probability of Failure, Line (8)

Line (8) lists the Element Effects Weighted Probability of Failure which is calculated from the applicable element fault tree found in Appendix B. In this instance, Figure 3-1 is the element fault tree for the Surge Relief System. Using the equation given in Figure 3-1, and inserting the appropriate Effects Weighted Probability of Failure for each piece of equipment in the fault tree, it is possible to calculate the Element Effects Weighted Probability of Failure.

Step 3 - Calculate the Benchmark Element Effects Weighted Probability of Failure, Line (9)

Line (9) lists the Benchmark Element Effects Weighted Probability of Failure which is calculated from the applicable element fault tree found in Appendix B. Again, using the equation in Figure 3-1, and inserting the Benchmark Effects Weighted Probability of Failure for each piece of equipment, it is possible to arrive at the Benchmark Element Effects Weighted Probability of Failure as shown in Table 3-4.

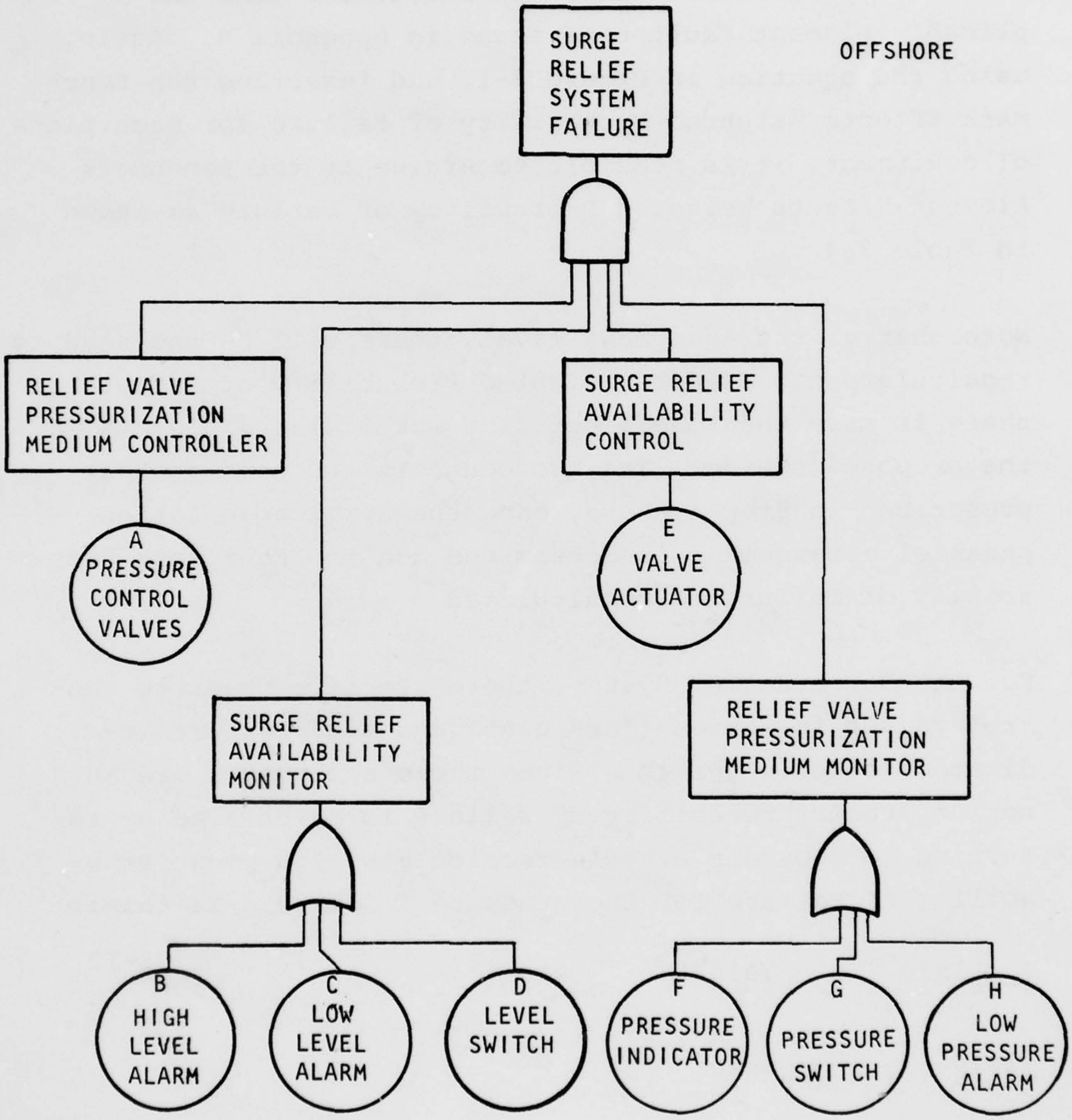
Note that at the equipment level, there will be the need to recalculate the Effects Weighted Probability of Failure if there is more than one piece of a particular equipment in the proposed system. The procedure is the same as that prescribed in Step 1 above, once the applicable series/parallel arrangement is determined and the Equipment Probability of Failure is recalculated.

For the Surge Relief System, there are five pressure control valves in series ("or" gate) and six pressure indicators also in series. Since these equipments are in series, their probability of failure is calculated by referring to Appendix B. The recalculated Equipment Probability of Failure for the pressure indicators is then:

$$1-(e^{1x10^{-12}} \cdot e^{1x10^{-12}} \cdot e^{1x10^{-12}} \cdot e^{1x10^{-12}} \cdot e^{1x10^{-12}}$$

$$e^{1x10^{-12}}) = 1-e^{6x10^{-12}}$$

or $6x10^{-12}$. This means that the pressure indicators have a very good probability of not failing. It also means that their reliability rating will approach one. They will never equal one, because no piece of equipment can be considered 100 percent reliable. Likewise for the pressure control valves, their probability of failure is:



P(failure) = A . (B + C + D) . E . (F + G + H)

Figure 3-1. Surge Relief System Fault Tree.

TABLE 3-4. ELEMENT/RELIABILITY/EFFECTS RATING SHEET

ELEMENT DESCRIPTION OFFSHORE SURGE RELIEF SYSTEM

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12241						
/01 Valve ACTUATOR	10^{-8}	10^{-12}	24	.358	3.58×10^{-9}	3.58×10^{-13}
12242						
/01 Level Switch	10^{-12}	10^{-12}	6	.090	9.0×10^{-14}	9.0×10^{-14}
/02 High Level ALARM	10^{-12}	10^{-12}	6	.090	9.0×10^{-14}	9.0×10^{-14}
/03 Low Level ALARM	10^{-12}	10^{-12}	1	.015	1.5×10^{-14}	1.5×10^{-14}
12243						
/01 Pressure Indicator	10^{-12}	10^{-12}	1	.015	1.5×10^{-14}	1.5×10^{-14}
/02 Pressure Switch	10^{-12}	10^{-12}	7	.104	1.04×10^{-13}	1.04×10^{-13}
/03 Alarm	10^{-12}	10^{-12}	7	.104	1.04×10^{-13}	1.04×10^{-13}
			$\sum F_i$ = (cont			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ______

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ______

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ ______

TABLE 3-4. (Cont.) ELEMENT/RELIABILITY/EFFECTS RATING SHEET

ELEMENT DESCRIPTION OFFSHORE SURGE RELIEF SYSTEM

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12244 /c1 Pressure Control valve	10^{-10}	10^{-12}	15	.224	2.24×10^{-11}	2.24×10^{-13}
			$\sum F_i = 67$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILIT OF FAILURE 3.49×10^{-45}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED I OBABILITY OF FAILURE 3.49×10^{-51}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .999

TABLE 3-5. EFFECTS WEIGHTING FACTOR WORKSHEET

OFFSHORE EQUIPMENT NUMBER	NAME	MAJOR SPILL A	MEDIUM SPILL B	MINOR SPILL C	CATASTROPHIC HAZARD D	CRITICAL HAZARD E	MARGINAL HAZARD F	NEGLIGIBLE HAZARD G	LONG DELAY H	SHORT DELAY I	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
12212	Temperature Monitor										
	/01 Temperature Indicator							1			1
12213	Flow Rate Monitor										
	/01 Measuring Device						7		5		12
	- Orifice Plate										
	- Sonic Meter										
	- P/D Meter										
	- Turbine Meter										
	/02 Flow Transmitter							1	5		6
	/03 Flow Indicator							1	5		6
12214	Flow Rate Controller										
	/01 Flow Regulator							1	5		6
	/02 Control Valve Activator							1	5		6
	/03 Limit Switches			8				1	5		14
	• SAMPLING										
12220	/01 Sampler							1			1
	• SURGE RELIEF SYSTEM										
12241	Surge Relief Availability Control										
	/01 Valve Actuator	10				9			5		24

TABLE 3-5. EFFECTS WEIGHTING FACTOR WORKSHEET
(Continued)

OFFSHORE EQUIPMENT NUMBER	NAME	MAJOR SPILL A	MEDIUM SPILL B	MINOR SPILL C	CATASTROPHIC HAZARD D	CRITICAL HAZARD E	MARGINAL HAZARD F	NEGLIGIBLE HAZARD G	LONG DELAY H	SHORT DELAY I	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
12242	Surge Relief Availability Monitor										
	/01 Level Switch							1	5		6
	/02 Alarm - High							1	5		6
	/03 Alarm - Low							1			1
12243	Relief Valve Pressurization Medium Monitor										
	/01 Pressure Indicator							1			1
	/02 Pressure Switch						7				7
	/03 Alarm - Low						7				7
12244	Relief Valve Pressurization Medium Controller										
	/01 Pressure Control Valves			8			7				15
	• DRAIN & SLOPS HANDLING										
12331	Drain Tank Level Monitor										
	/01 Level Switch		9								9
	/02 Alarm			8							8

TABLE 3-6. FAILURE EFFECTS WEIGHTING FACTORS

FAILURE EFFECTS		WEIGHTING FACTOR FOR DETRIMENTAL EFFECT OF CONTROL COMPONENT FAILURE ON THE IMPORT OF OIL
A.	Major oil spill	10
B.	Medium oil spill	9
C.	Minor oil spill	8
D.	Catastrophic hazard level	10
E.	Critical hazard level	9
F.	Marginal hazard level	7
G.	Negligible hazard level	1
H.	Long delay	5
I.	Short delay	3

Definitions of Failure Effects

A. will release more than 100,000 gallons of oil [1]

B. will release between 10,000 to 100,000 gallons of oil [2]

C. will release less than 10,000 gallons of oil [1]

D. will cause death or severe injury to personnel, or system loss [2]

E. will cause personnel injury or major system damage, or will require immediate corrective action for personnel or system survival [2]

F. can be counteracted or controlled without injury to personnel or major system damage [2]

G. will not result in personnel injury or system damage [2]

H. will delay the import of oil by more than 1 hour

I. will delay the import of oil by less than 1 hour

[1] Reference 1

[2] Reference 3

$$1-(e^{1x10^{-10}} \cdot e^{1x10^{-10}} \cdot e^{1x10^{-10}} \cdot e^{1x10^{-10}} \cdot e^{1x10^{-10}})$$

$$= 1-e^{5x10^{-10}}$$

or $5x10^{-10}$. The new Effects Weighted Probability of Failure is then $9.0x10^{-14}$ and $1.12x10^{-10}$ respectively. These values are entered as shown in Table 3-7. Substituting the Effects Weighted Probability of Failure into the applicable Failure equation in Figure 3-1, we get:

$$\begin{aligned} P\ (\text{Failure}) = {} & (1.12x10^{-10}) \cdot (9.0x10^{-14} + 9.0x10^{-14} + \\ & 1.5x10^{-14}) \cdot 3.58x10^{-9} \cdot (9.0x10^{-14} + \\ & 1.04x10^{-13} + 1.04x10^{-13}) \\ = {} & 2.33x10^{-44} \text{ as the Element Effects Probability of Failure.} \end{aligned}$$

Similarly, the Benchmark Element Effects Weighted Probability of Failure is calculated by substituting the Benchmark Effects Weighted Probability of Failure into the same Element Probability Equation in Figure 3-1 as done in the calculations above.

$$\begin{aligned} P\ (\text{Failure}) = {} & (1.04x10^{-12}) \cdot (9.0x10^{-14} + 9.0x10^{-14} + \\ & 1.5x10^{-14}) \times (3.58x10^{-13}) \times (9.0x10^{-14} + \\ & 1.04x10^{-13} + 1.12x10^{-12}) \\ = {} & 9.54x10^{-50} \text{ as the Benchmark Effects Probability of Failure} \end{aligned}$$

TABLE 3-7. ELEMENT/RELIABILITY/EFFECTS RATING SHEET

ELEMENT DESCRIPTION OFFSHORE SURGE RELIEF SYSTEM.

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12241						
/01 Valve Actuator	10^{-8}	10^{-12}	24	.358	3.58×10^{-9}	3.58×10^{-13}
12242						
/01 Level Switch	10^{-12}	10^{-12}	6	.090	9.0×10^{-14}	9.0×10^{-14}
/02 High level Alarm	10^{-12}	10^{-12}	6	.090	9.0×10^{-14}	9.0×10^{-14}
/03 Low level Alarm	10^{-12}	10^{-12}	1	.090	1.5×10^{-14}	1.5×10^{-14}
12243						
/01 Pressure Indicator	6×10^{-12}	6×10^{-12}	1	.015	9.0×10^{-14}	9.0×10^{-14}
/02 Pressure Switch	10^{-12}	10^{-12}	7	.104.	1.04×10^{-13}	1.04×10^{-13}
/03 Alarm.	10^{-12}	10^{-12}	7	.104	1.04×10^{-13}	1.04×10^{-13}
			$\sum F_i$ = (CONT)			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE __________

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE __________

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ __________

TABLE 3-7. (Cont.) ELEMENT/RELIABILITY/EFFECTS RATING SHEET

ELEMENT DESCRIPTION OFFSHORE SURGE RELIEF SYSTEM.

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12244						
/01 Pressure control Valve	5×10^{-10}	5×10^{-12}	15	.224	1.12×10^{-10}	1.12×10^{-12}
			$\sum F_i = 67$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.33×10^{-44}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 9.54×10^{-30}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .999

Step 4 - Calculate the Normalized Element Reliability

Once the Element Effects Weighted Probability of Failure (Step 2), and the Benchmark Element Effects Weighted Probability of Failure (Step 3) are calculated, the Normalized Element Reliability Rating can be calculated by the expression:

$$\left.\begin{array}{l} 1-(\text{Step } 3 \div \text{Step } 2) \\ \qquad\text{or} \\ 1-(\text{Line } 9 \div \text{Line } 8) \end{array}\right\} = \text{Normalized Element Reliability Rating}$$

For example, it is now possible to calculate the Normalized Element Reliability Rating for the Surge Relief Systems as follows:

$1-(9.54\times10^{-50} \div 2.33\times10^{-44}) = .999$ is the Surge Relief System's Reliability Rating.

This same procedure is utilized for all the control equipment elements found in a Deepwater Port.

Step 5 - Compare the Element Effects Weighted Probability of Failure with the Benchmark Element Effects Weighted Probability of Failure

This comparison is intended to be a relative one. As more Deepwater Ports are reviewed and their performance documented, the design reviewer will be able to establish a more definitive benchmark system. In the interim, the system, as mentioned in Step 3, should be considered the benchmark system.

Step 6 - Calculate the Control System Effects Weighted Probability of Failure

Once the Element Effects Weighted Probability of Failure is calculated for all elements, the Control System Effects Weighted Probability of Failure is readily calculated. Because of the definition of the Elements, their relationship for reliability purpose is in series. Thus, the Control System Effects Weighted Probability of Failure is the product of all the Element Effects Weighted Probabilities of Failure.

APPENDIX A

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

NOTE

Mean Barrels to Failure figures were obtained from actual DWP operational statistics from two DWP's in the Carribean. These figures are identified by an asterisk (*). The remaining MBTF are estimates based on failure rates for similar equipment found in the WASH-1400 report. Since the failure rates were based on time of operation or cycles and were converted to Barrels of oil throughput on engineering judgment and DWP volumes, there remains uncertainty as to the accuracy of these particular MBTFs. As more actual data are gathered, these data should be updated.

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11100 LINE UP TANKER SYSTEM
ELEMENTS (2) 11110 LINE UP VALVES ON TANKER

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
11111 Valve Line Up Monitor							
/01 Remote Indicator	Assures proper valve line up	A) Bulb burn-out	Delay in pumping oil from tanker; requires visual checks	G,I	1×10^{12} BBL	Filament burnout; age; electrical short in wiring and circuitry	Use test button periodically to check circuit continuities of indicator panel
		B) Circuitry Failure	Same as above	G,I	1×10^{12} BBL	Same as above	Same as above
/02 Local Indicator	Assures proper value line up	Stems and valve actuators fail to rise when valve is open.	No visual confirmation of valve line up. Requires manual cycling of the valves.	G,H	1×10^{12} BBL	Act of nature; human error; mechanical wear, possible stem breakage.	Check when locally cycling valve
11112 Valve Line Up Controller							
/01 Push Button Remote	Regulates proper valve line up	A) Button contacts worn	Delay in lining up valves, thus requiring push button local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	On failure, check circuit continuity and repair
		B) Circuitry Failure	Same as above	G,I	1×10^{11} BBL	Same as above	Same as above
/02 Push Button Local	Regulates proper valve line up	A) Button contacts worn	Delay in lining up valves thus requiring manual local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	Same as above
		B) Circuitry failure	Same as above	G,I	1×10^{11} BBL	Same as above	Same as above
/03 Manual Local	Regulates proper valve line up	A) Manpower unavailable to open or close valves manually	Inability to achieve valve line up until manpower opens or closes valves.	G,H	1×10^{12} BBL	Not enough available manpower	Periodic manual cycling recommended to ensure manual readiness

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11100 LINE UP TANKER SYSTEM
ELEMENTS (2) 11110 LINE UP VALVES ON TANKER (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/04 Valve Actuator	Opens or closes valve	A) Circuitry failure	Limit switches will not be tripped, thus indicating improper valve line up. Fails to open or close valve.	F,H	1×10^8 BBL	Age; electrical short in wiring and circuitry; corrosion	Periodic lubrication and inspection
		B) Jammed gears	Same as above	F,H	1×10^8 BBL	Same as above	Same as above

AD-A060 144 HARRIS (FREDERIC R) INC NEW YORK F/G 15/5
STUDY OF DEEPWATER PORT OIL TRANSFER CONTROL SYSTEMS.(U)
JUN 78 I C ROBSON, W W SCHERKENBACH DOT-CG-64503-A
UNCLASSIFIED USCG-D-58-78 NL

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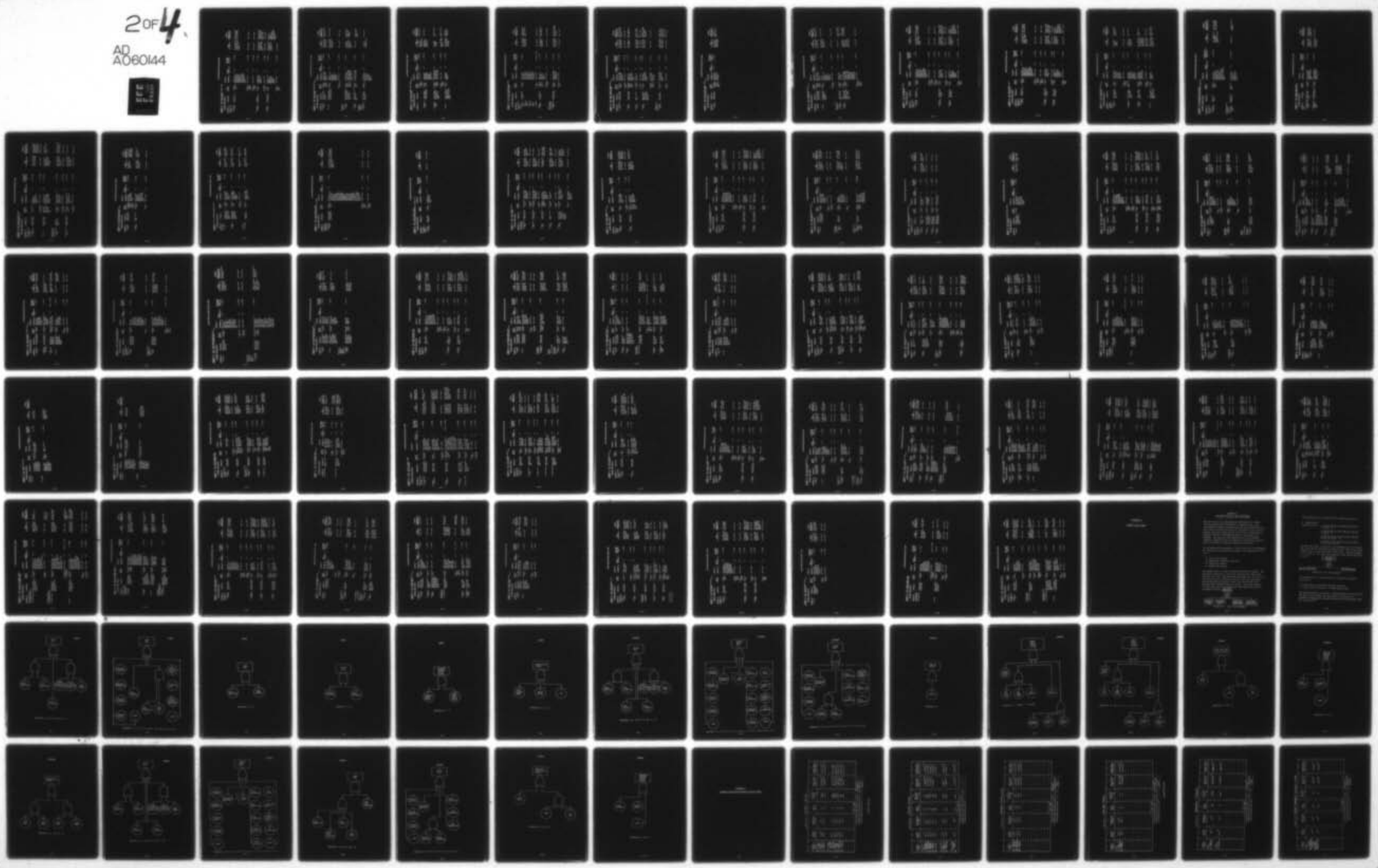

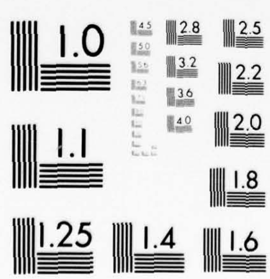
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1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11200 MOVE OIL THROUGH TANKER SYSTEM
ELEMENTS (2) 11210 START PUMPING

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
11211 Pressure Monitor							
/01 Pressure Indicator	Denotes oil pressure in line	A) Needle indicator stuck	False high pressure reading could result in premature pump shutdown. False low pressure readings could result in rupture of tanker piping with possible spills.	C,F,I	1×10^{12}BBL	Oil sludge blockage of tap; cold weather (freezing); incorrect calibration.	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows rupture	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
/02 Pressure Transmitter	Transmits pressure signal	A) Circuit fails	Zero pressure readings could result in pump shutdown.	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion; lightning.	Repair or replace on failure. Use redundant equipment if reliability is low.
		B) Spurious signals	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/03 Pressure Recorder	Records pressure vs. time history	A) Clock fails	No hard copy of pressure. Readings; no pumping delay if pressure indicator operable.	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion.	Periodic inspection necessary to ensure accurate output and proper paper supply for recorder.
		B) Pen or thermal print fails	Same as above	G,I	1×10^{12}BBL	Same as above	

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11200 MOVE OIL THROUGH TANKER SYSTEM
ELEMENTS (2) 11210 START PUMPING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/04 Pressure Switch	Shuts down pumps if high line pressure	A) Bourdon tube or bellows rupture	Fails to shut-down pump, could result in line rupture.	C,F,I	1×10^{10} BBL	Electrical short in wiring and circuitry; age.	Repair or replace on failure.
/05 Alarm	Notifies operator of extremely low or high line pressures.	A) Bulb burnout	Fails to visually & audibly alert operator of significant pressure increases or decreases.	C,F,I	1×10^{12}BBL	Age; electrical short in wiring and circuitry; corrosion.	Periodic testing
		B) Horn malfunction	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
11212 Flow Controller							
/01 Speed Regulator	Regulates pumping rate by opening or closing valve to steam feed of turbine pump	A) Valve actuator fails to control steam feed line	Valve failing to close or open properly may cause steam turbine pump to over pressurize the line and rupture it.	C,F,H	1×10^{8} BBL	Cold weather (freezing) incorrect calibration age; electrical short	Periodic lubrication and inspection reccommended
/02 Speed Indicator	Indicates rpm's of steam turbine pump	A) Internal circuit fails	No visual confirmation of pump speed	G	1×10^{12}BBL	Same as above	Periodic inspection and calibration
11213 Pump Protection Devices							
/01 Overspeed Trip	Turns off pump due to excessive pump rpm's	A) Spring/ balls fail	Steam turbine pump continues to run at uncontrollable rate, thus jeopardizing tanker pipeline	E,H	1×10^{10} BBL	Age; stress; corrosion bearing failure	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11200 MOVE OIL THROUGH TANKER SYSTEM
ELEMENTS (2) 11210 START PUMPING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
		B) Other internal failure	Same as above	E,H	1×10^{10} BBL	Age; stress; corrosion bearing failure	Same as above
/02 Temperature Switch	Turns off pump if high temperatures are detected	A) Thermocouple fails	Catastrophic pump and/or steam turbine fails due to continued operation at high temperature	E,H	1×10^{10} BBL	Thermocouple burnout; tap blocked; age; corrosion	Same as above
/03 Low Lube Pressure Trip	Turns off pump and steam turbine if low lube pressure indicated	A) Bourdon tube or bellows rupture	Catastrophic pump and/or steam turbine failure due tc low lube levels	E,H	1×10^{10} BBL	Oil sludge blockage; corrosion	Periodic inspection
		B) Other internal failure	Same as above	E,H	1×10^{10} BBL	Age; oil sludge blockage; corrosion	Periodic inspection
/04 Alarm	Turns on alarm if excess in either temperature, overspeed, or low lube exists	A) Circuit fails	Catastrophic pump/turbine failure	E,H	1×10^{10} BBL	Age; corrosion; electrical short in circuitry and wiring	Periodic inspection and calibration

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11200 MOVE OIL THROUGH TANKER SYSTEM
ELEMENTS (2) 11220 SWITCH TANKS ON TANKERS

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	EQUIPMENT IDENTIFICATION: FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
11221 Tank Level Monitor							
/01 Level Indicator • Float gage read switch • Float gage tape • Metric tape	Indicates tank quantities	A) Circuit fails	Fails to indicate proper tank levels; float stuck in low position will result in premature tank switching; float stuck in high position will result in low suction	G,I	1×10^{12} BBL	Age; electrical short in wiring and circuitry; sludge buildup	Redundant indicators and/or periodic maintenance
• Pneumatic		B) Float stuck	Same as above	G,I	$(6\text{-}100) \times 10^{6}$ BBL	Same as above	Same as above
/02 Manual Dipping	Indicates tank quuanities	A) Manpower unavailable to dip	Inability to gage tanks levels until arrival of manpower	G,I	1×10^{12} BBL	Not enough available manpower; human error	Make backup personnel available.
		B) Incorrect readings	Same as above	G,I	1×10^{12} BBL	Same as above	Train personnel
11222 Value Line Up Controller							
/01 Push Button Remote	Initate valve position change	A) Button contacts worn	Delay in lining up valves, thus requiring push button local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry	Upon failure, check circuitry continuity and repair
		B) Circuitry fails	Same as above	G,I	1×10^{11} BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11200 MOVE OIL THROUGH TANKER SYSTEM
ELEMENTS (2) 11220 SWITCH TANKS ON TANKERS (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/02 Push Button Local	Initiates valve position change	A) Button contacts worn	Delay in lining up valves thus requiring manual local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry	Upon failure check circuit continuity, and repair
		B) Circuitry fails	Same as above	G,I	1×10^{11} BBL	Same as above	Same as above
/03 Manual local	Initiates valve position change	A) Manpower unavailable or in adequate	Inability to achieve valve line up until manpower opens or closes valves	G,I	1×10^{12} BBL	Not enough available manpower	Make backup personnel available
/04 Valve Actuator	Opens or closes valve	A) Circuitry failure	Fails to open or close	F,H	1×10^{8} BBL	Age; electrical short in wiring and circuitry	Periodic lubrication and inspection
		B) Jammed	Same as above	F,H	1×10^{8} BBL	Same as above	Same as above
/05 Limit Switches	Shuts off valve actuator when valve opens or closes; acts as valve interlock mechanism	A) Circuit fails	Remote indicators will not confirm opening or closing of valves	F,H,	1×10^{6} BBL	Age; electrical short in wiring and circuitry	Redundant or backup limit switches to ensure overall reliability
		B) Contacts fail due mechanical wear	Valve interlock fails to block other valve operations	F,H,	3×10^{9} BBL	Same as above	Same as above
11223 Valve Line Up Monitor							
/01 Remote indicator	Assures proper valve line up	A) Bulb burnout	Delay in pumping oil from tank; requires visual check	C,F,I	1×10^{12}BBL	Filament burnout; age; electrical short in wiring and circuitry	Use test button periodically to to check circuit continuities of indicator panel
		B) Circuit fails	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11200 MOVE OIL THROUGH TANKER SYSTEM
ELEMENTS (2) 11220 SWITCH TANKS ON TANKER (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/02 Local indicator	Assures proper valve line up	A) Stems on actuators fail to rise when valve is open	No visual confirmation of valve line up; requires manual check	C,F,I	1×10^{12}BBL	Act of nature; human error; mechanical wear; steam breakage	Check when locally cycling valve

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11300 SHUTDOWN TANKER SYSTEM
ELEMENTS (2) 11310 STOP PUMPING (Cont.)

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	EQUIPMENT IDENTIFICATION: FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
/04 Pressure Switch	Shuts down pumps if high discharge pressure occurs	A) Bourdon tube or bellows rupture	Fails to shut-down pump, could result in line rupture.	C,F,I	1×10^{11} BBL	Electrical short in wiring and circuitry; age.	Repair or replace on failure.
/05 Alarm	Notifies operator of extremely low or high line pressure	A) Bulb burnout	Fails to visually & audibly alert operator of significant pressure increases or decreases.	C,F,I	1×10^{12} BBL	Age; electrical short in wiring and circuitry; corrosion.	Periodic testing
		B) Horn malfunction	Same as above	C,F,I	1×10^{12} BBL	Same as above	Same as above
11312 Flow Rate Controller							
/01 Speed Indicator	Indicates rpm's of steam turbine pump	A) Internal circuit fails	No visual confirmation of pump speed	G	1×10^{12} BBL	Same as above	Periodic inspection and calibration
/02 Speed Regulator	Regulates proper pumping rate by opening or closing valve to steam feed of turbine pump	A) Gears jammed in valve actuator	Valve failing to close causes system pressurization with line ruptures, pump overloads, etc.; Valve failing to open causes pumping and tank emptying irregularities	C,F,H	1×10^{8} BBL	Cold weather (freezing); incorrect calibration; age; electrical short in wiring and circuitry.	Periodic inspection, cleaning, and lubrication.
		B) Failure of electro/hydraulic control system	Same as above	C,F,H	1×10^{8} BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11300 SHUTDOWN TANKER SYSTEM
ELEMENTS (2) 11310 STOP PUMPING

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
11311 Pressure Monitor							
/01 Pressure Indicator	Denotes oil pressure in line	A) Needle indicator stuck	False high pressure reading could result in premature pump shutdown. False low pressure readings could result in rupture of tanker piping with possible spills.	C,F,I	1×10^{12}BBL	Oil sludge blockage of tap; cold weather (freezing); incorrect calibration.	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows rupture	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
/02 Pressure Transmitter	Transmits pressure signal to recorder	A) Circuit fails	Zero pressure readings could result in pump shutdown.	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion; lightning.	Repair or replace on failure. Use redundant equipment if reliability is low.
		B) Spurious signals	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/03 Pressure Recorder	Records a pressure versus time history	A) Clock fails	No hard copy of pressure. Readings; no pumping delay if pressure indicator operable.	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion.	Periodic inspection necessary to ensure accurate output and proper paper supply for recorder.
		B) Pen or thermal print fails	Same as above	G,I	1×10^{12}BBL	Same as above	Repair on failure

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11300 SHUTDOWN TANKER SYSTEM
ELEMENTS (2) 11310 STOP PUMPING

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	EQUIPMENT IDENTIFICATION: FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
11311 Pressure Monitor							
/01 Pressure Indicator	Denotes oil pressure in line	A) Needle indicator stuck	False high pressure reading could result in premature pump shutdown. False low pressure readings could result in rupture of tanker piping with possible spills.	C,F,I	1×10^{12}BBL	Oil sludge blockage of tap; cold weather (freezing); incorrect calibration.	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows rupture	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
/02 Pressure Transmitter	Transmits pressure signal to recorder	A) Circuit fails	Zero pressure readings could result in pump shutdown.	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion; lightning.	Repair or replace on failure. Use redundant equipment if reliability is low.
		B) Spurious signals	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/03 Pressure Recorder	Records a pressure versus time history	A) Clock fails	No hard copy of pressure. Readings; no pumping delay if pressure indicator operable.	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion.	Periodic inspection necessary to ensure accurate output and proper paper supply for recorder.
		B) Pen or thermal print fails	Same as above	G,I	1×10^{12}BBL	Same as above	Repair on failure

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11300 SHUTDOWN TANKER SYSTEM
ELEMENTS (2) 11310 STOP PUMPING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
11313 Pump Protection Devices							
/01 Overspeed Trip	Turns off pump due to excessive pump rpm's	A) Spring/ balls fail	Steam turbine pump continues to run at uncontrollable rate, thus jeopardizing tanker pipeline	E,H	1×10^{10} BBL	Age; stress; corrosion; bearing failure	Periodic inspection and calibration
		B) Other internal failure	Same as above	E,H	1×10^{10} BBL	Same as above	Same as above
/02 Temperature Switch	Turns off pump if high temperatures are detected	Thermocouple fails	Catastrophic pump and/or steam turbine fails due to continued operation at high temperatures	E,H	1×10^{10} BBL	Thermocouple burnout; tap blocked; age; corrosion	Same as above
/03 Low Lube Pressure Trip	Turns off pump due to low lubrication	A) Bourdon tube or bellows ruptures	Catastrophic pump and/or steam turbine failure due to low lube levels	E,H	1×10^{10} BBL	Age; electrical short in wiring and circuitry; oil sludge blockage; corrosion; bearing failure	Periodic maintenance
		B) Other internal failure	Same as above	E,H	1×10^{10} BBL	Age; oil sludge blockage; corrosion	Same as above
/04 Alarm	Turns on alarm if either excess temperature, overspeed, or low lube exists	A) Circuit fails	Catastrophic pump/turbine failure	E,H	1×10^{10} BBL	Age; corrosion electrical short in circuitry and wiring	Periodic inspection and calibration

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11300 SHUTDOWN TANKER SYSTEM
ELEMENTS (2) 11320 DISPLACE OIL FROM HOSE/LOADING ARM

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS BETWEEN FAILURES (MTBF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
11321 Pressure Monitor							
/01 Pressure Indicator	Denotes oil pressure	A) Needle indicator stuck	False high pressure readings result in premature pump shutdown. False low pressure readings result in rupture of tanker piping with possible spill.	C,F,I	1×10^{12} BBL	Oil sludge on tap; cold weather (freezing); incorrect calibration	Periodic inspection, cleaning, and calibration
11322 Hose/Loading Arm Drain							
/01 Manual Procedure Local	Empties hose/ loading arm	Drain left closed	Oil spill will occur if disconnect is attempted without draining lines.	G,I	25×10^{6} BBL	Human error	Properly trained personnel

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11300 SHUTDOWN TANKER SYSTEM
ELEMENTS (2) 11330 EMERGENCY SHUTDOWN SYSTEM

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
11330							
/01 Midships remote Pump shutdown Switch	Shutsdown ships steam turbine pumps.	A) Circuitry failure	Delay in shutdown; requires control room shutdown or shutdown from pump room.		1×10^{10} BBL	Electrical short in wiring and circuitry; age; corrosion.	Periodic testing and inspection to ensure proper operation.
/02 Control room Remote pump Shutdown Switch	Shutsdown ships steam turbine pumps	B) Circuitry failure	Delay in shutdown; requires midships shutdown or shutdown from pump room.		1×10^{10} BBL	Electrical short in wiring and circuitry; age.	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11300 SHUTDOWN TANKER SYSTEM
ELEMENTS (2) 11340 CLOSE TANKER VALVES

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
11341 Valve Line Up Monitor							
/01 Remote Indicator	Assures proper valve line up	A) Bulb burn-out	Delay in pumping oil from tanker; requires visual checks	G,I	1×10^{12} BBL	Filament burnout; age; electrical short in wiring	Use test button periodically to check circuit continuities of indicator panel
		B) Circuitry Failure	Same as above	G,I	1×10^{12} BBL	Same as above	Same as above
/02 Local	Assures proper value line up	Stems and valve actuators fail to rise when valve is open.	No visual confirmation of valves closing. Requires manual cycling of the valves.	G,H	1×10^{12} BBL	Act of nature; human error; mechanical wear, possible stem breakage.	Check when locally cycling valve
11341 Valve Line Up Controller							
/01 Push Button Remote	Regulates proper valve line up	A) Button contacts worn	Delay in closing valves, thus requiring push button local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	On failure, check circuit continuity and repair
		B) Circuitry Failure	Same as above	G,I	1×10^{11} BBL	Same as above	Same as above
/02 Push Button Local	Regulates proper valve line up	A) Button contacts worn	Delay in closing valves thus requiring manual local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	Same as above
		B) Circuitry failure	Same as above	G,I	1×10^{11} BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11300 SHUTDOWN TANKER SYSTEM
ELEMENTS (2) 11340 CLOSE TANKER VALVES (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON			SOLUTION	
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/03 Manual Local	Regulates proper valve line up	A) Manpower unavailable to open or close valves manually	Inability to close valves until manpower opens or closes valves.	G,H	1×10^{12} BBL	Not enough available manpower	Periodic manual cycling recommended to ensure manual readiness
/04 Valve Actuator	Opens or closes valve	A) Circuitry failure	Limit switches will not be tripped, thus indicating improper valve line up. Fails to open or close valve.	F,H	1×10^{8} BBL	Age; electrical short in wiring and circuitry; corrosion	Periodic lubrication and inspection
		B) Jammed	Same as above	F,H	1×10^{8} BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 11400 TANKER COMMUNICATIONS SYSTEM
ELEMENTS (2)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
11410 Radio							
/01 VHF	Provides tanker communications with offshore or onshore control center	A) Internal circuit fails	No two-way radio communications between tanker and control center	G,I	1×10^{12}BBL	Electrical short in circuitry and wiring.	Initiate walkie-talkie or visual communication
/02 Walkie-Talkie	Provides tanker communications with personnel on short-range basis	A) Internal circuit fails	No short range two-way communications between tanker and personnel on foot	G,I	1×10^{12}BBL	Electrical short in circuitry and wiring.	Initiate visual communication
		B) Battery wears down	Same as above	G,I	1×10^{12}BBL	Battery wears out from use	Replace with new battery
11420 Voice							
/01 SP Phone	Direct line communication	A) Break in wire	No direct linkup by wire between tanker and control center	G,I	1×10^{12}BBL	Electrical short in circuitry and wiring.	Initiate radio communications

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12100 LINE UP OFFSHORE SYSTEM
ELEMENTS (2) 12110 HOSE/LOADING ARM CONNECTION TO TANKER

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12111 Oil In Hose/Loading Arm Detector							
/01 Pressure Indicator	Detects presence of fluid in the hose/loading arm	A) Needle indicator stuck	False high pressure readings will result in premature conclusion of a fluid in the hose/loading arm. This will result in draining the hose/loading arm and delay pumping. Likewise, false low pressure readings will result in a premature conclusion of no fluids in the hose/loading arm and cause possible damage to the arm as it is moved, or aid spill if hose is uncapped prior to connection to tanker manifold	C,F,H	1×10^{12} BBL	Oil sludge blockage of tap; cold weather (freezing); incorrect calibrations.	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows fail	Same as above	C,F,H	1×10^{12} BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,H	1×10^{12} BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12100 LINE UP OFFSHORE SYSTEM
ELEMENTS (2) 12110 HOSE/LOADING ARM CONNECTION TO TANKER (Cont.)

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
12112 Hose/ Loading Arm Drain							
/01 Manual Procedure	Empties hose/ loading arm	A) Drain left open	As soon as pumping begins, oil spill will occur	G,H	25×10^6 BBL*	Human error	Train personnel

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12100 LINE UP OFFSHORE SYSTEM
ELEMENTS (2) 12120 LINE UP VALVES

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12121 Valve Line Up Controller							
/01 Push Button Remote	Regulates proper valve line up	A) Button contacts worn	Delay in lining up valves, thus requiring push button local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	Upon failure, check circuit continuity and repair
		B) Circuitry failure	Same as above	G,I	1×10^{11} BBL	Same as above	Same as above
/02 Push Button Local	Regulates proper valve line up	A) Button contacts worn	Delay in lining up valves, thus requiring push button local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	Same as above
		B) Circuitry fails	Same as above		1×10^{11} BBL	Same as above	Same as above
/03 Manual Local	Regulates proper valve line up	A) Manpower unavailable or inadequate	Inability to achieve valve line up until manpower opens or closes valves	G,H	1×10^{12} BBL	Not enough available manpower	Periodic manual cycling to ensure manual readiness
/04 Valve Actuator	Opens or closes valve	A) Circuitry failure	Fails to open or close		1×10^{8} BBL	Age; electrical short in wiring and circuitry corrosion.	Periodic inspection and lubrication
		B) Jammed gears	Same as above	F,H	1×10^{8} BBL	Same as above	Same as above
/05 Limit Switches	Shuts off valve actuator when valve opens or closes. Acts as a valve interlock mechanism	A) Circuitry fails	Remote indicators will not confirm opening or closing of valves	C,F,H	3×10^{9} BBL	Age; electrical short in wiring and circuitry; corrosion.	Redundant or backup limit switches to ensure overall reliability
		B) Contacts fail	Valve interlock fails to block other valve operations	C,F,H	3×10^{9} BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12100 LINE UP OFFSHORE SYSTEM
ELEMENTS (2) 12120 LINE UP VALVES (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12122 Valve Line Up Monitor							
/01 Remote Indicator	Assures proper valve line up	A) Bulb burnout	Delay in pumping oil from tanker, requires visual check	G,I	1×10^{12} BBL	Filament burnout; age; electrical short in wiring and circuitry.	Use test button periodically to check circuit continuities of indicator panel
		B) Circuitry failure	Same as above	G,I	1×10^{12} BBL	Same as above	Same as above
/02 Local Indicator	Assures point valve line up	A) Stems on valve activators fail to rise when valve is open	No visual confirmation of valve line up, requires manual cycling of the valves	G,H	1×10^{12} BBL	Act of nature; human error; mechanical wear; posssible stem breakage	Check when locally cycling valve

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12200 MOVE THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12210 ESTABLISH FLOW

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12211 Pressure Monitor							
/01 Pressure Indicator	Donates proper oil pressure in line	A) Needle indicator stuck	False high pressure readings result in reduced throughput. False low pressure readings could result in rupture of offshore piping with possible spill	C,F,I	1×10^{12} BBL	Oil sludge blockage of tap; cold weather (freezing); incorrect calibration.	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows rupture	Same as above	C,F,I	1×10^{12} BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,I	1×10^{12} BBL	Same as above	Same as above
/02 Pressure Transmitter	Transmits pressure signal to recorder	A) Circuit fails	Zero pressure reading will result in pump shutdown.	G,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion.	Repair or replace on failure. Use redundant equipment if reliability is low.
		B) Spurious signals	Same as above	G,I	1×10^{12} BBL	Same as above	Same as above
/03 Pressure Recorder	Record a pressure versus time history	A) Clock fails	No hard copy of pressure readings	G,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion.	Periodic inspection necessary to ensure accurate output and proper paper supply for recorder.
		B) Pen or thermal print fails	Same as above	G,I	1×10^{12} BBL	Same as above	Repair on failure

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12200 MOVE THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12210 ESTABLISH FLOW (Cont.)

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
/04 Alarm	Notifies operator of extremely low or high pressure	A) Circuit failure	Fails to visibly and audibly alert operator of significant pressure increases or decreases	C,F,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion.	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above	C,F,I	1×10^{12} BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	C,F,I	1×10^{12} BBL	Same as above	Same as above
12212 Temperature Monitor							
/01 Temperature Indicator	Indicates oil temperature	A) Needle indicator stuck	False high temperature readings will result in false volume calculations and wrong pump speeds	G	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion; incorrect calibration	Periodic inspection, cleaning, and calibration
		B) Bulb breaks;	Same as above	G	1×10^{12} BBL	Same as above	Same as above
12213 Flow Rate Monitor							
/01 Measuring Device • Orifice • Sonic Meter	Meters fluid flow rate	A) Metering device jammed or blocked	False flow rates result in incorrect volume calculation for custody transfer; pumping delays or stoppages if used for leak detection	F,H	1×10^{8} BBL 14×10^{6} BBL	Oil sludge blockage; cold weather (freezing); incorrect calibration.	Isolate blockage and remove. Periodic cleaning and inspection

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12200 MOVE THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12210 ESTABLISH FLOW (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12214 Flow Rate Controller							
/01 Flow Indicator	Indicates flow rate at a remote location	A) Circuitry fails	No visual verification of flow rate	G,H	1×10^{12}BBL	Age; electrical shorts in wiring and circuitry; corrosion	Periodic inspection and calibration
/02 Flow Controller	Acts on signal from transmitter and operates the flow regulator	A) Circuitry fails	Cause imbalance and damage to flow regulator	F,H	1×10^{12}BBL	Same as above	Same as above
/03 Flow Transmitter	Transmits flow rate signal to flow controller	A) Circuitry fails	Same as above	G,H	1×10^{12}BBL	Same as above	Same as above
/04 Flow Regulator	Regulates flow rates by opening or closing valves	A) Circuitry fails	Results in flow rate fluctuations	F,H	1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12220 MOVE OIL THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12220 SAMPLING

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/01 Sampler	Samples crude oil for quality control and liability purposes	A) Jammed	Valve failing to close results in possible oil spill. Valve failing to open will result in no crude samples.	G	1×10^{10} BBL	Age; corrosion, mechanical wear	Periodic inspection and lubrication

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12200 MOVE OIL THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12230 BOOSTER PUMPING

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12231 Pressure Monitor							
/01 Pressure Indicator	Donates proper oil pressure in line	A) Needle indicator stuck	False high pressure readings result in premature pump shutdown. False high pressure readings result in rupture of offshore piping with possible oil spill.	C,F,I	1×10^{12} BBL	Material blockage of tap; cold weather (freezing); incorrect calibration.	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows rupture	Same as above	C,F,I	1×10^{12} BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,I	1×10^{12} BBL	Same as above	Same as above
/02 Pressure Transmitter	Transmits pressure signal to recorder	A) Circuit fails	Zero pressure readings will result in pump shutdown	G,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion.	Repair or replace on failure. Use redundant equipment if reliability is low
		B) Spurious signals	Same as above	G,I	1×10^{12} BBL	Same as above	Same as above
/03 Pressure Recorder	Records a pressure versus time history	A) Clock fails	No hard copy of pressure readings	G,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic inspection of paper supply
		B) Pen or thermal print fails	Same as above	G,I	1×10^{12} BBL	Same as above	Repair on failure
/04 Pressure Switch	Shuts down pumps if high discharge pressure occurs	A) Bourdon tube or bellows rupture	Fails to shutdown pump, could result in line rupture	C,F,I	1×10^{10} BBL	Electrical short in wiring and circuitry; age.	Repair or replace on failure.

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12200 MOVE OIL THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12230 BOOSTER PUMPING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/05 Alarm	Notifies operator of extremely low or high line pressures	A) Circuitry failure	Fails to visually and audibly alert operator of significant pressure increases or decreases	C,F,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic testing
		B) Bulb burnout	Same as above		1×10^{12} BBL	Same as above	Same as above
		C) Horn malfunction	Same as above		1×10^{12} BBL	Same as above	Same as above
12232 Temperature Monitor							
/01 Temperature Indicator	Indicates oil temperature	A) Needle indicator stuck	False high temperature readings will result in false volume calculations and wrong pump speeds	G	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic inspection, cleaning, and calibration
		B) Bulb breaks	Same as above	G	1×10^{12} BBL	Same as above	Same as above
12233 Flow Monitor							
/01 Flow Element							
12234 Flow Rate Controller							
/01 Flow Transmitter	Transmits flow rate signal to signal selector	A) Circuitry fails	Cause imbalance and damage to flow controller	G,H	1×10^{12} BBL	Age; electrical short in wiring and circuitry; corrosion	Periodic inspection and calibration

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12200 MOVE OIL THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12230 BOOSTER PUMPING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/02 Flow Controller	Regulates flow rates by opening or closing valves	A) Circuitry fails	Results in flow rate fluctuations and possible controller damage	F,H	1×10^{12} BBL	Same as above	Same as above
/03 Pressure Controller	Equalizes tanker and offshore pressures	A) Circuitry fails	Same as above	F,H	1×10^{12} BBL	Same as above	Same as above
/04 Signal Selector	Compares flow rate signals from tanker and offshore pumping stations and equalizes the flow rates via the flow controller	A) Circuitry fails	Same as above	G,H	1×10^{12} BBL	Same as above	Same as above
/05 Flow Regulator	Controls pump speed thus maintaining desired flow rate	A) Jammed or blocked	Results in possible damage to pump	C,F,H	1×10^{12} BBL	Age; electrical short in wiring and circuitry; and sludge blockage	Periodic inspection, cleaning, and lubrication
12235 Pump Protection Devices							
/01 Level Switch	Turn off pumps if packing glands leak excessively	A) Circuitry failure	Electrical short and/or float stuck in low position will result in pumps continuing to run. Float stuck in high position will shut off pumps.	C,F,I	1×10^{10} BBL	Age; electrical short in wiring and circuitry; oil sludge blockage; corrosion; bearing failure	Periodic testing and inspection
		B) Float stuck in high or low position	Same as above	C,F,I	$(6\text{-}100) \times 10^{6}$ BBL*	Same as above	Redundant floats and/or maintenance

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12200 MOVE OIL THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12230 BOOSTER PUMPING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/02 Vibration Switch	Turns off pumps due to excess vibration	A) Pendulum fails	Excess vibrations fail to shut off pumps, excess temperature will shut off pumps	E,H	1×10^4 BBL	Oil sludge blockage, bearing failure	Periodic testing and inspection
/03 Differential pressure switch	Turns off pumps if low suction occurs	A) Circuitry failure	Fails to shutdown pumps; result in a line rupture and possible oil spill	E,H	1×10^4 BBL	Low suction occuring such as when tank levels are low	Same as above
/04 Air Eliminator	Bleeds off any trapped air in line before it reaches pumps	A) Float does not seal air outlet	Improper float seal will result in a minor spill	C,F,I	$(6\text{-}100) \times 10^6$ BBL*	Corrosion; sludge blockage; leaky float	Periodic inspection and cleaning
/05 Alarm	Notifies operator the pumps are either leaking, vibrating, drawing a low suction	A) Circuitry failure	Results in a short delay as the operator will not immediately be aware	F	1×10^{12}BBL	Same as above	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above	F	1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	F	1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12200 FLOW THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12240 RELIEF OF PRESSURE SURGES

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12241 Surge Relief Availability Control							
/01 Valve Actuator	Opens or Closes surge relief system to main offshore pipeline	A) Circuitry failure	Failing to close will result in possible overflow of surge tank, failing to open will isolate surge tank from main offshore pipeline and put main pipeline in jeopardy of rupturing	A,E,H	1×10^8 BBL	Age; electrical short in wiring and circuitry, corrosion	Periodic lubrication and inspection
		B) Jammed	Same as above		1×10^8 BBL	Same as above	Same as above
12242 Surge Relief Availability Monitor							
/01 Level Switch	Indicates high fluid levels in surge tank and sets off alarm	A) Circuitry failure	Electrical short and/or float stuck in high position will set off high level alarm. Electrical short and/or float stuck in low position could result in oil spill	G,H	1×10^{12} BBL	Age; electrical short in wiring and circuitry; oil sludge blockage; corrosion	Periodic inspection and cleaning
		B) Float stuck in high or low position	Same as above		$(6\text{-}100) \times 10^6$ BBL*	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12200 FLOW THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12240 RELIEF OF PRESSURE SURGES (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/02 Alarm	Notifies operator of fluid level in surge tank	A) Circuitry failure	Fails to visually alert operator of high levels in surge tank, thus creating possible spill. Low levels could indicate leak from the main transfer line	G,H	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic inspection and testing
		B) Bulb burn-out	Same as above	G,H	1×10^{12} BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	G,H	1×10^{12} BBL	Same as above	Same as above
12243 Relief Valve Pressurization Medium Monitor							
/01 Pressure Indicator	Denotes proper inert gas pressure for surge relief system	A) False high or low pressure readings	False high pressure readings will result in setting lower value pressures and the surge tank filling prematurely. False low pressure readings will result in many pressure surges not being relieved and pipeline being overstressed.	G	1×10^{12} BBL	Material blockage of tap; cold weather (freezing): incorrect calibrations	Periodic inspection, cleaning, and calibration

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12200 FLOW THROUGH OFFSHORE SYSTEM
ELEMENTS (2) 12240 RELIEF OF PRESSURE SURGES (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/02 Pressure Switch	Sets off alarm if inert gas pressure to surge relief valve actuator and control valves is low	A) Circuitry failure	Fails to actuate alarm; resultant low pressure will result in tank filling	F	1×10^{10} BBL	Electrical short in wiring and circuitry; age; corrosion	Repair or replace a failure
/03 Alarm	Notifies operator of low surge relief inert gas pressure. Results in switching to standby inert gas supply	A) Circuitry failure	Fails to visually and audibly alert operator of low pressure in inert gas supply	F	1×10^{12}BBL	Electrical short in wiring and curcuitry; age corrosion	Periodic testing
12244 Relief Valve Pressurization Medium Controller							
/01 Pressure Control Valves	Controls back pressure applied to relief valves by inert gas which is overcome by a relief surge	A) Low pressure of inert gas supply	Surge relief tank would prematurely fill	C,F	1×10^{10} BBL	Age; electrical short in wiring and circuitry corrosion; low inert gas supply	Periodic inspection

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12300 SHUTDOWN OFFSHORE SYSTEM
ELEMENTS (2) 12310 BOOSTER PUMPING SHUTDOWN

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12311 Pressure Monitor							
/01 Pressure Indicator	Denotes proper oil pressure in line	A) Needle indicator stuck	False high pressure readings result in premature pump shutdown. False high pressure readings result in rupture of offshore piping with possible oil spill	C,F,I	1×10^{12}BBL	Material blockage of tap; cold weather (freezing); incorrect calibration	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows rupture	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
/02 Pressure transmitter	Transmits pressure signal to recorder	A) Circuit fails	Zero pressure reading will result in pump shutdown	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Repair or replace on failure. Use redundant equipment if reliability is low
		B) Spurious signals	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/03 Pressure Recorder	Records a pressure versus time history	A) Clock fails	No hard copy of pressure readings	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic inspection necessary to ensure accurate output and proper paper supply for recorder
		B) Pen or thermal print fails	Same as above	G,I	1×10^{12}BBL	Same as above	Repair or replace on failure

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12300 SHUTDOWN OFFSHORE SYSTEM
ELEMENTS (2) 12310 BOOSTER PUMPING SHUTDOWN (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/04 Pressure Switch	Shuts down pumps if high discharge pressure occurs	A) Bourdon tube or bellows rupture	Fails to shut-down pump, could result in line rupture	C,F,I	1×10^{10} BBL	Electrical short in wiring and circuitry; age	Repair or replace on failure
/05 Alarm	Notifies operator of extremely low or high pressures	A) Circuitry failure	Fails to visually and audibly alert operator of significant pressure increases or decreases	C,F,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above		1×10^{12} BBL	Same as above	Same as above
		C) Horn malfunction	Same as above			Same as above	Same as above
12312 Temperature Monitor							
/01 Temperature Indicator	Indicates proper oil temperature	A) False high temperature readings	False high temperature readings will result in pump shutdown	G	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion; incorrect calibration	Periodic inspection, cleaning, and calibration
12313 Flow Monitor							
/01 Flow element							
12314 Flow Rate Controller							
/01 Flow Transmitter	Transmits flow rate signal to indicator	A) Circuitry failure	Could cause pump speed to vary from overspeed to stop	G,H	1×10^{12} BBL	Age; electrical short in wiring and circuitry	Repair or replace on failure
/02 Flow Regulator	Controls pump speed, thus maintaining desired flow rate	A) Jammed or blocked	Same as above	C,F,H	1×10^{12} BBL	Age, electrical short in wiring and circuitry; oil sludge blockage	Periodic inspection, cleaning, and lubrication

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12300 SHUTDOWN OFFSHORE SYSTEM
ELEMENTS (2) 12310 BOOSTER PUMPING SHUTDOWN (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/03 Flow Controller	Regulates flow rates by opening or closing valves	A) Circuitry fails	Results in flow rate fluctuations and possible controller damage	F,H	1×10^{12} BBL	Same as above	Same as above
/04 Pressure Controller	Equalizes tanker and offshore pressures	A) Circuitry fails	Same as above	F,H	1×10^{12} BBL	Same as above	Same as above
/05 Signal Selector	Compares flow rate signals from tanker and offshore pumping stations and equalizes the flow rates via the flow controller	A) Circuitry fails	Same as above	G,H	1×10^{12} BBL	Same as above	Same as above
12315 Pump Protection Devices							
/01 Level Switch	Turns off pumps if packing glands leak excessively	A) Circuitry failure	Electrical short and/or float stuck in low position will result in pumps continuing to run	C,F,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; oil sludge blockage; corrosion; bearing failure	Periodic testing and inspection
		B) Float stuck in high or low position	Float stuck in high position will shut off pump	C,F,I	$(6\text{-}100) \times 10^{6}$ BBL*	Same as above	Same as above
/02 Vibration Switch	Turns off pumps due to excess vibration	A) Circuitry failure	Excess vibrations fail to shut off pumps. Excess temperature will shut off pumps	E,H	1×10^{12} BBL	Oil sludge; blockage; bearing failure	Same as above
/03 Differential Pressure Switch	Turns off pumps if low suction occurs	A) Circuitry failure	Pump continues to run with lack of fluid. Excess temperature and vibrations shut pumps off	E,H	1×10^{12} BBL	Low suction occurring such as when tank levels are low	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12300 SHUTDOWN OFFSHORE SYSTEM
ELEMENTS (2) 12310 BOOSTER PUMPING SHUTDOWN (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/04 Air Eliminator	Bleeds off any trapped air in line before it reaches pumps	A) Float does not seal air outlet	Improper float seal will result in a minor spill	C,F,I	$(6\text{-}100) \times 10^6$ BBL*	Corrosion; sludge blockage; leaky float	Periodic inspection and cleaning
/05 Alarm	Notifies operator the pumps are either leaking, vibrating, drawing a low suction	A) Circuitry failure	Results in a short delay as the operator will not immediately be aware	F	1×10^{12}BBL	Same as above	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above	F	1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	F	1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12300 SHUTDOWN OFFSHORE SYSTEM
ELEMENTS (2) 12320 PACK SYSTEM

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
12321 Valve Line Up Monitor							
/01 Remote Indicator	Assures proper valve line up	A) Bulb burnout	Delays in packing system; requires visual checks	G,I	1×10^{12} BBL	Filament burnout; age; electrical short in wiring and circuitry; corrosion	Use test button periodically to check circuit continuities of indicator panel
		B) Circuitry failure	Same as above	G,I	1×10^{12} BBL	Same as above	Same as above
/02 Local Indicator	Assures proper valve line up	A) Stems of valve actuators fail to rise when valve is open	No visual confirmation of valve line up; requires manual cycling of the valves	G,H	1×10^{12} BBL	Act of nature; human error; mechanical wear; possible stem breakage	Check when locally cycling valve
12322 Valve Line Up Controller							
/01 Push Button Remote	Regulates proper valve line up	A) Button contacts worn	Delay in lining up valves, thus requiring push button local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	Upon failure, check circuit continuities and repair
		B) Circuitry failure	Same as above		1×10^{11} BBL	Same as above	Same as above
/02 Push Button Local	Regulates proper valve line up	A) Button contacts worn	Delay in lining up valves; thus requiring manual local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	Same as above
		B) Circuitry failure	Same as above		1×10^{11} BBL	Same as above	Same as above
/03 Manual Local	Regulates proper valve line up	A) Manpower unavailable to open or close valves manually	Inability to achieve line up until manpower opens or closes valves	G,H	1×10^{12} BBL	Not enough available manpower	Periodic manual cycling to ensure manual readiness

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12300 SHUTDOWN OFFSHORE SYSTEM
ELEMENTS (2) 12320 PACK SYSTEM (Cont.)

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
/04 Valve Actuator	Opens or closes valve	A) Circuitry failure	Fails to open or close	F,H	1×10^{8} BBL	Age; electrical short in wiring and circuitry; corrosion	Repair or replace on failure
		B) Jammed Gears	Same as above	F,H	1×10^{8} BBL	Same as above	Same as above
/05 Limit Switches	Shuts off valve actuator when valve opens or closes; acts as a valve interlock mechanism	A) Circuitry failure	Remote indicators will not confirm opening or closing of valves	C,F,H	3×10^{9} BBL	Age; electrical short in wiring and circuitry; corrosion	Redundant limit switches
		B) Contacts fail	Valve interlock fails to block other valve operations	C,F,H	3×10^{9} BBL	Same as above	Same as above
12323 Pressure Monitor							
/01 Pressure Indicator	Denotes proper oil pressure in pipeline	A) Needle indicator stuck	False high pressure readings will fail to completely pack offshore piping. False low pressure readings may result in overstressing and rupturing the pipeline	C,F,I	1×10^{12} BBL	Oil sludge blockage of tap; cold weather (freezing); incorrect calibration	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows rupture	Same as above	C,F,I	1×10^{12} BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,I	1×10^{12} BBL	Same as above	Same as above
/02 Pressure Transmitter	Transmits pressure signal to recorder	A) Circuit fails	Zero pressure readings; thus uncertainty of packed system	G,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion	Repair or replace on failure. Use redundant equipment if reliability is low

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12300 SHUTDOWN OFFSHORE SYSTEM
ELEMENTS (2) 12320 PACK SYSTEM (Cont.)

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
		B) Spurious signals	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/03 Pressure Recorder	Records a pressure versus time history	A) Clock fails	No hard copy of pressure readings	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic inspection necessary to ensure accurate output and proper paper supply for recorder
		B) Pen or thermal print fails	Same as above	G,I	1×10^{12}BBL	Same as above	Repair or replace on failure
/04 Alarm	Notifies operator of extremely low or high line pressure	A) Circuitry failure	Fails to visually and audibly alert operator of significant pressure increase or decrease	C,F,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above		1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above		1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12300 SHUTDOWN OFFSHORE SYSTEM
ELEMENTS (2) 12330 DRAIN AND SLOPS HANDLING

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12331 Drain Tank Level Monitor							
/01 Level Switch	Detects high or low fluid level in drain tank	A) Circuitry failure	Level switch stuck in high position will cause unnecessary draining of drain/slop tank; level switch stuck in low position may result in oil overflow	B	3×10^9 BBL	Age; electrical short in wiring and circuitry; corrosion	Periodic testing and inspection
		B) Float stuck in high or low position	Same as above		$(6\text{-}100) \times 10^6$ BBL*	Same as above	Same as above
/02 Alarm	Notifies operator of high or low fluid levels in drain/slop tank	A) Circuitry failure	Fails to usually and audibly alert operator of low fluid levels in drain/slop tank	C	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic testing
		B) Bulb burnout	Same as above	C	1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	C	1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12300 SHUTDOWN OFFSHORE SYSTEM
ELEMENTS (2) 12340 EMERGENCY SHUTDOWN SYSTEM

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
12341 Valve Monitor							
/01 Remote Indicator	Assures proper line up of emergency shutdown valve	A) Bulb burnout	It will become immediately apparent if the emergency shutdown valve closes but is not indicated at the control panel	F	1×10^{12}BBL	Filament burnout; age; electrical short in wiring and circuitry; corrosion	Use test button periodically to check circuit continuities of indicator panel
		B) Circuitry failure	Same as above	F	1×10^{12}BBL	Same as above	Same as above
12342 Valve Line Up Controller							
/01 Valve Actuator	Opens or closes emergency shutdown valves	A) Hydraulic failure	If valve fails to close when needed, a major oil spill could occur. If valve closes prematurely, a pressure shock will result with possible need for surge relief system	A	1×10^{8} BBL	Cold weather (freezing); age; mechanical wear; mechanical seizing	Periodic cycling and maintenance checks
		B) Pneumatic failure	Same as above	A	1×10^{8} BBL	Same as above	Same as above
		C) Gearing or mechanical failure	Same as above	A	1×10^{8} BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12300 SHUTDOWN OFFSHORE SYSTEM
ELEMENTS (2) 12340 EMERGENCY SHUTDOWN SYSTEM (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12343 Valve Actuating Medium Monitor							
/01 Pressure Switch	Monitors the pressure of the inert gas supply to valve actuator; low pressure sets off alarm	A) Circuitry failure	If no reserve supply of inert gas, then emergency shutdown valve will have to be manually cycled	B	1×10^{10} BBL	Electrical short; age; wear	Redundant equipments to increase reliability
/02 Alarm	Notifies operator of low pressure in the inert gas supply	A) Circuitry failure	Fails to visually and audibly alert operator of significant pressure increases or decreases	B	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic testing and inspection
		B) Bulb burnout		B	1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction		B	1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12400 COMMUNICATION SYSTEM
ELEMENTS (2) 12410 VOICE

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12411 Wire							
	Provides direct non-interference voice communication between offshore and onshore control points	A) Cable link up failure	Delay in communications, requiring use of radio		1×10^{12}BBL	Break in cable; corrosion; age	
12412 Radio							
	Provides direct communication between mobile personnel on offshore facilities and the central control point	A) Radio's fail to operate	Delay in communications		1×10^{12}BBL	Age of electrical components batteries in walkie-talkie	

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 12400 COMMUNICATION SYSTEM
ELEMENTS (2) 12420 DATA

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
12421 Wire							
	Provides direct non-interference data communication (i.e. pressure, temperature, valve line up readings, etc.) between offshore and onshore control points	A) Cable link up failure	Delay in communications; requiring use of radio		1×10^{12} BBL	Break in cable; corrosion, age	
12422 Radio							
	Provides direct data communications between onshore and offshore points. Used when offshore and onshore controls are distant	A) Radio fails to operate	Delay in communication		1×10^{12} BBL	Age of electrical components; electrical short in wiring and circuitry	

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13100 LINE UP ONSHORE SYSTEM
ELEMENTS (2) 13110 LINE UP MANIFOLD VALVES

EQUIPMENT IDENTIFICATION			EFFECTS ON			SOLUTION	
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13111 Value line up Indicator							
/01 Remote Indicator	Assures proper value line up	A) Bulb	Delay in pumping oil into tanks,	G,I	1×10^{12}BBL	Filament burnout; age; electrical short in wiring and circuitry; corrosion	Use test button periodically to check circuit continuities of indicator panel
		B) Circuitry failure	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/02 Local Indicator	Assures proper value line up	A) Stems on value actuators fail to rise when valve is open.	No visual confirmation of value line up; requires manual cycling of the valves.	G.H	1×10^{12}BBL	Act of Nature; human error; mechanical wear; possible stem breakage	Check when locally cycling valve
13112 Valve Line Up Controller							
/01 Push button Remote	Regulates proper valve line up	A) Button contacts worn	Delays in lining up valves, thus requiring push bottom local.	G,I	1×10^{11} BBL	Age; Electrical short in wiring and circuitry corrosion.	Upon failure, check circuit continuity and repair
		B) Circuitry failure	Same as above	G,I	1×10^{11} BBL	Same as above	Same as above
/02 Push Button local	Regulates proper valve line up	A) Button contacts worn	Delay in lining up valves thus requiring manual local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry corrosion.	Same as above
/03 Manual Local	Regulates proper valve line up	A) Manpower unavailable to open or close valves manually.	Inability to achieve valve line up until manpower opens or closes valves.	G,H	1×10^{11} BBL	Not enough available manpower.	Periodic manual cycling to ensure manual readiness.

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13100 LINE UP ONSHORE SYSTEM
ELEMENTS (2) 13110 LINE UP MANIFOLD VALVES (Con't.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/04 Valve Actuator	Opens or closes valves.	A) Circuitry failure	Limit switches will not be tripped: Thus indicating improper valve line up.	F,H	1×10^8 BBL	Age; Electrical short in wiring and circuitry corrosion.	Repair or replace on failure.
		B) Jammed Gearing	Same as above	F,H	1×10^8 BBL	Same as above	Periodic lubrication and inspection recommended
/05 Limit Switches	Shuts off valve actuator when valve opens or closes.	A) Circuitry failure	Remote indicator will not confirm opening or closing of valves.	C,F,H	3×10^9 BBL	Age; Electrical short in wiring and circuitry corrosion.	Redundant of back-up limit switches to ensure overall reliability.
		B) Mechanical wear of components	Same as above	C,F,H	3×10^9 BBL	Same as above	

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13100 LINE UP ONSHORE SYSTEM
ELEMENTS (2) 13120 TANK SELECTION

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13121 Tank Level Monitor							
/01 Level transmitter	Transmits signal of tank levels to remote indicator	A) Circuitry failure	Delay in pumping into tank; required visual checks of local indicator; may need to switch tanks	I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion.	Repair or replace on failure
/02 Remote Indicator	Denotes fluid level in tanks	A) Bulb Burnout	Delay in pumping into tank; requires visual check of local indicator; may need to switch tanks	I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion.	Use test button periodically to check circuit continuties of indicator panel
		B) Circuitry failure	Same as above	I	1×10^{12} BBL	Same as above	Same as above
/03 Local Indicator	Denotes fluid levels in tanks	A) Float stuck in high or low position	If remote indicator fails and float stuck in high position. Tank will be switched before properly filled. Float stuck in low position may result in tank being over filled	I	$(6\text{-}100) \times 10^{6}$ BBL	Electrical short in wiring and circuitry; age; corrosion; oil sludge blockage	Locally check when near tanks; use redundant floats and/or periodic maintenance.
/04 Level switches	Sets off level alarm if tank levels are high	A) Circuitry failure	Fails to shut off tank inlet/outlet valve. Tank will over fill.	I	1×10^{12} BBL	Electrical short in wiring and circuitry; age corrosion.	Periodic inspection and cleaning.
/05 Level alarm	Notifies operator of high tank levels	A) Circuitry failure	Fails to visually and audibly alert operator of high tank levels.	C,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion.	Periodic testing and inspection.
		B) Bulb burnout	Same as above	C,I	1×10^{12} BBL	Same as above	Same as above
		C) Horn Malfunction	Same as above	C,I	1×10^{12} BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13100 LINE UP ONSHORE SYSTEM
ELEMENTS (2) 13120 TANK SLECTION (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON			SOLUTION	
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13122 Tank Valve Controller							
/01 Push button Remote	Regulates proper valve line up to tank.	A) Button contacts worn.	Delay in selecting tank; thus requiring push button local.	G.I	$1 X 10^{11}$ BBL	Electrical short in wiring and circuitry; age; corrosion.	Upon failure check circuit continuity and repair.
		B) Circuitry failure	Same as above	G,I		Same as above	Same as above
/02 Push button Local	Regulates proper valve line up to tank.	A) Button contracts worn.	Delay in selecting tank, thus requiring manual local.	G.I	$1 X 10^{11}$ BBL	Eelectrical short in wiring and circuitry; age; corrosion.	Same as above
		B) Circuitry failure.	Same as above	G,I	$1 X 10^{11}$ BBL	Same as above	Same as above
/03 Manual local	Regulates proper valve line up to tank.	A) Manpower unavailable to open or close valves manually.	Inability to select proper tank until manpower opens or closes valves.	G.H	$1 X 10^{12}$ BBL	Not enough available man power.	Periodic manual cycling to ensure manual readiness.
/04 Valve Actuator	Opens or closes valves to tanks.	A) Fails to open or close tank inlet/outlet valves.	Limit switches will not be tripped; thus indicating improper tank selection.	F,H	$1 X 10^{11}$ BBLS	Electrical short in wiring and circuitry; age; corrosion.	Periodic lubrication and inspection.
/05 Limit Switches	Shuts off valve actuator when valve opens or closes.	A) Circuitry failure.	Remote indicators will not confirm opening or closing of valves.	C,F,H	$3 X 10^9$ BBLS	Electrical short in wiring and circuitry; age; corrosion.	Redundant limit switches.
		B) Mechanical wear of component.	Same as above	C,F,H	$3 X 10^9$ BBLS	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13100 LINE UP ONSHORE SYSTEM
ELEMENTS (2) 13120 TANK SELECTION (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13123 Tank Valve Monitor							
/01 Remote Indicator	Assures proper tank valve line up.	A) Bulb burnout.	Delay in pumping oil into tanks. Requires visual check.	G,I	1×10^{12}BBL	F. lament burnout; age; electrical short in wiring & circuitory; corrosion.	Use test button periodically to check circuit continuities of indicator parel.
		B) Circuitry failure.	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/02 Local Indicator	Assures proper valve line up.	A) Stems on valve actuators fail to rise when valves open.	No visual confirmation of valve line up, requires manual cycling of the valves.	G,H	1×10^{12}BBL	Act of nature; human error; mechanical wear; possible stem breakage.	Check when locally cycling valve.

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13200 MOVE OIL TO ONSHORE STORAGE
ELEMENTS (2) 13210 BOOSTER PUMPING

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	EQUIPMENT IDENTIFICATION: FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
13211 Pressure Monitor							
/01 Pressure Indicator	Denotes proper oil pressure in pipeline	A) Needle indicator stuck	False high pressure readings result in reduced throughput. False low pressure readings could result in rupture of pipeline with possible oil spill	C,F,I	1×10^{12}BBL	Oil sludge blockage of tap; cold weather (freezing); incorrect calibration	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows rupture	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
/02 Pressure Transmitter	Transmits pressure signal to recorder	A) Circuit fails	Zero pressure readings will result in pump shutdown	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Repair or replace on failure. Use redundant equipment if reliability is low
		B) Spurious signals	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/03 Pressure Recorder	Records pressure versus time history	A) Clock fails	No hard copies of pressure readings	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age corrosion	Periodic inspection necessary to ensure accurate output and proper paper supply for recorder
		B) Pen or thermal print fails	Same as above	G,I	1×10^{12}BBL	Same as above	

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13200 MOVE OIL TO ONSHORE STORAGE
ELEMENTS (2) 13210 BOOSTER PUMPING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/04 Pressure Switch	Shuts down pumps if high discharge pressure occurs	A) Circuitry failure	Fails to shut-down pumps; results in line rupture and oil spill	F,I	1×10^{10} BBL*	Electrical short in wiring and circuitry; age; corrosion	Repair or replace on failure
/05 Alarm	Notifies operator of extremely low or high pressures	A) Circuitry failure	Fails to visually and audibly alert operator of significant pressure increases or decreases	C,F,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
13212 Temperature Monitor							
/01 Temperature Indicator	Indicates oil temperature	A) Needle indicator stuck	False high temperature readings will result in false volume calculations and wrong pump speeds	G	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion; incorrect calibration	Periodic inspection and calibration
		B) Bulb breaks;	Same as above	G	1×10^{12}BBL	Same as above	Same as above
13213 Flow Monitor							
/01 Flow Element							
13214 Flow Rate Controller							
/01 Flow Transmitter	Transmits flow rate signal to indicator	A) Circuitry failure	Cause imbalance and damage to flow controller	G,H	1×10^{12}BBL	Age; electrical short in circuitry and wiring	Periodic inspection and calibration

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13200 MOVE OIL TO ONSHORE STORAGE
ELEMENTS (2) 13210 BOOSTER PUMPING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/01 Flow Regulator	Controls pump speed thus maintaining desired flow rate	A) Jammed or blocked	Results in possible damage to pump	C,F,H	1×10^{12} BBL	Age; electrical short in wiring and circuitry; and sludge blockage	Periodic inspection, cleaning, and lubrication
/02 Flow Controller	Regulates flow rates by opening or closing valves	A) Circuitry fails	Results in flow rate fluctuations and possible controller damage	F,H	1×10^{12} BBL	Same as above	Same as above
/03 Pressure Controller	Equalizes offshore and onshore pressures	A) Circuitry fails	Same as above	F,H	1×10^{12} BBL	Same as above	Same as above
/04 Signal Selector	Compares flow rate signals from tanker and offshore pumping stations and equalizes the flow rates via the flow controller	A) Circuitry fails	Same as above	G,H	1×10^{12} BBL	Same as above	Same as above
13215 Pump Protection Devices							
/01 Level Switch	Turns off pumps if packing glands leak excessively	A) Circuitry failure	Electrical short and/or float stuck in low position will result in pumps continuing to run. Float stuck in high position will shut off pumps	C,F,I	3×10^{9} BBL	Electrical short in wiring and circuitry; age; oil sludge blockage; corrosion; bearing failure	Periodic testing and inspection
		B) Float stuck in high or low position	Same as above	C,F,I	$(6\text{-}100) \times 10^{6}$ BBL*	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13200 MOVE OIL TO ONSHORE STORAGE
ELEMENTS (2) 13210 BOOSTER PUMPING (Cont.)

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
/02 Vibration Switch	Turns off pumps due to excess vibration	A) Pendulum fails	Excess vibrations fail to shut off pumps; excess temperature will shut off pumps	E.H	1×10^{10} BBL	Oil sludge blockage: bearing failure	Same as above
/03 Differential Pressure Switch	Turns off pumps if low suction occurs	A) Circuitry failure	Pump continues to run with lack of fluid. Excess temperature and vibration will shut off pump	E,H	1×10^{10} BBL	Low suction occurring such as when tank is low	Same as above
/04 Air Eliminator	Bleeds off any trapped air in line before it reaches pumps	A) Float does not seal air outlet	Improper float seal will result in a minor spill	C.F.I	1×10^{12}BBL	Corrosion: sludge blockage; leaky float	Periodic inspection and cleaning
/05 Alarm	Notifies operator the pumps are either leaking, vibrating, drawing a low suction	A) Circuitry failure	Results in a short delay as the operator will not immediately be aware	F	1×10^{12}BBL	Same as above	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above	F	1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	F	1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13200 MOVE OIL TO ONSHORE STORAGE
ELEMENTS (2) 13220 TANK SWITCHING

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
13221 Tank Valve Line Up Monitor							
/01 Remote Indicator	Assures proper valve line up	A) Bulb burnout	Delay in pumping oil into tanks; requires visual check	G,I	1×10^{12}BBL	Filament burnout; age; electrical short in wiring and circuitry; corrosion	Use test button periodically to check circuit continuities of indicator panel
		B) Circuitry failure	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/02 Local Indicator	Assures proper valve line up	A) Stems on valve actuators fail to rise when valve's open	No visual confirmation of valve line up; requires manual cycling of the valves	G,H		Act of nature; human error; mechanical wear; possible stem breakage	Check when locally cycling valve
13222 Tank Level Monitor							
/01 Level Transmitter	Transmits tank level signal to remote and local indicators	A) Circuitry failure	Delay in pumping oil; requires switching to another tank	I	1×10^{12}BBL	Age; electrical short in wiring and circuitry; corrosion	Repair or replace on failure
/02 Remote Indicator	Denotes proper tank levels	A) Circuitry failure	Delay in pumping oil requires visual check of local indicator	I	1×10^{12}BBL	Age; electrical short in wiring and circuitry; corrosion	Use test button periodically to check circuit continuities of indicator panel
		B) Bulb burnout	Same as above	I	1×10^{12}BBL	Same as above	Same as above
/03 Local Indicator	Denotes proper tank levels	A) Float stuck in high or low position	Electrical short and/or float stuck in low position will result in pumps continuing to run. Float stuck in high position will shut off pumps	I	$(6\text{-}100) \times 10^{6}$ BBL*	Age; electrical short in wiring and circuitry; corrosion; sludge blockage	Redundant floats and/or periodic maintenance

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13200 MOVE OIL TO ONSHORE STORAGE
ELEMENTS (2) 13220 TANK SWITCHING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/04 Level Switches	Close tank inlet valve if tank level is high	A) Circuitry failure	Electrical short and/or float stuck in low position will result in pumps continuing to run. Float stuck in high position will shut off pumps	I	3×10^9 BBL	Age; electrical short in wiring and circuitry; corrosion; mechanical wear	Periodic testing and inspection
		B) Float stuck in high	Same as above	I	$(6\text{-}100) \times 10^6$ BBL*	Same as above	Same as above
/05 Level Alarm	Notifies operator of extremely high tank levels	A) Circuitry failure	Fails to visually and audibly alert operator of significant oil levels increases or decreases in tanks	C,I	1×10^{12}BBL	Age; electrical short in wiring and circuitry; corrosion	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above	C,I	1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	C,I	1×10^{12}BBL	Same as above	Same as above
13223 Manifold and Tank Valve Line Up Controller							
/01 Push Button Remote	Regulates proper valve line up	A) Button contacts worn	Delay in switching tanks, thus requiring push button local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	Upon failure, check circuit continuity and repair
		B) Circuitry failure	Same as above	G,I	1×10^{11} BBL	Same as above	Same as above
/02 Push Button Local	Regulates proper valve line up	A) Button contacts worn	Delay in switching tanks thus requiring manual local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	Same as above
		B) Circuitry failure	Same as above	G,I	1×10^{11} BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13200 MOVE OIL TO ONSHORE STORAGE
ELEMENTS (2) 13220 TANK SWITCHING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/03 Manual Local	Regulates proper valve line up	A) Manpower unavailable to open or close valves manually	Inability to switch tanks until manpower opens or closes valves	G,H	1×10^{12} BBL	Age; electrical short in wiring and circuitry; corrosion	Periodic manual cycling to ensure manual readiness
/04 Valve Actuator	Opens or closes valves	A) Fails to open or close tank inlet/outlet valves	Limit switches will not be tripped, thus indicating improper tank switching	F,H	1×10^{8} BBL	Age; electrical short in wiring and circuitry; corrosion	Periodic inspection and lubrication
/05 Limit Switches	Shuts off valve actuator when valve opens or closes	A) Circuitry failure	Remote indicators will not confirm opening or closing of valves	C,F,H	3×10^{9} BBL	Age; electrical short in wiring and circuitry; corrosion	Redundant or backup limit switches to ensure overall reliability
		B) Mechanical wear of components	Same as above	C,F,H	3×10^{9} BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13200 MOVE OIL TO ONSHORE STORAGE
ELEMENTS (2) 13240 RELIEF OF PRESSURE SURGES

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13241 Surge Relief Availability Control							
/01 Valve Actuator	Opens or closes surge relief system to main offshore pipe line.	A) Circuitry failure.	Failing to close will result in possible overflow of surge tank. From main offshore pipeline, and put main pipeline in veopardy of rupturing.	A,E,H	1×10^8 BBL	Age; Electrical short in wiring and circuitry; corrosion.	Periodic inspection and
		B) Jammed gearing.	Same as above	A,E,H	1×10^8 BBL	Same as above	Periodic inspection and lubrication
13242 Surge Relief Availability Monitor							
/01 Level switch	Indicates high fluid levels in surge tank and sets off alram.	A) Circuitry failure	Electrical short and/or float stuck in high position will set off high level alarm; electrical short and/or float stuck in low position could result in oil spill.	G,H	1×10^{12} BBL	Age; electrical short in wiring and circuitry; corrosion.	Periodic testing and inspection.
		B) Float stuck in high or low position	Same as above	G,H	(6-100) X 10 BBL*	Same as above	Redundant floats and/or maintenance.
/02 Alarm	Notifies operator of high fluid level in surge tank.	A) Circuitry failure	Fails to visually and audibly alert operator of high levels in surge tank, thus creator a possible spill; low levels could indicate leak from the main transfer line.	G.H	1×10^{12}BBL	Electrical short in wiring and circuitry; age; cor-	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above	G,H	1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	G,H	1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13200 MOVE OIL TO ONSHORE STORAGE
ELEMENTS (2) 13240 RELIEF OF PRESSURE SURGES (con't)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13243 Relief Valve Pressurization Medium Monitor							
/01 Pressure indicator	Denotes proper inert gas pressure for surge relief system.	A) False high or low pressure readings.	False high pressure readings will result in setting lower valve pressures and the surge tank filling prematurly false low pressure readings will result in many pressure surges not being relieved and the pipeline being over stressed.	G	1 X 10^{12}BBL	Material blockage of tap; cold weather (freezing) incorrect calibration.	Periodic inspetion; cleaning and calibration.
/02 Pressure Switch	Sets off alarm if insert gas pressure to surge relief valve actuator and control valves is low.	A) Circuitry failure	Fails to actuate alarm; resultant-low pressure will result in tank filling.	F	1 X 10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion.	Repair or replace on failure
/03 Alarm	Notifies operator of low surge relief inert gas pressure.	A) Circuitry failure	Fails to usually and audibly alert operator of low pressure in the inert gas supply	F	1 X 10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion.	Periodic testing to ensure proper working order
13244 Relief Valve Pressurization Medium Controller							
/01 Pressure Control valves	Back pressure applied to control valves by inert gas is overcome by relief surges.	A) Low pressure of inert gas supply.	Surge relief tank would prematurally fill.	F	1 X 10^{10} BBL	Age; electrical short in wiring and circuitry; corrosion.	Periodic inspection.

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13300 SHUTDOWN ONSHORE SYSTEM
ELEMENTS (2) 13310 BOOSTER PUMPING

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13311 Pressure Monitor							
/01 Pressure Indicator	Denotes proper oil pressure in line	A) Needle indicator stuck	False high pressure readings result in premature pump shutdown. False high pressure readings result in rupture of onshore piping with possible oil spill	C,F,I	1×10^{12}BBL	Material blockage of tap; cold weather (freezing); incorrect calibration	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows rupture	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
/02 Pressure Transmitter	Transmits pressure signal to recorder	A) Circuit fails	Zero pressure readings will result in pump shutdown	G,I	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion	Repair or replace on failure. Use redundant equipment if reliability is low
		B) Spurious signals	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/03 Pressure Recorder	Records pressure versus time history	A) Clock fails	No hard copy of pressure readings	G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic inspection necessary to ensure accurate output and proper paper supply for recorder
		B) Pen or thermal print fails	Same as above	G,I	1×10^{12}BBL	Same as above	Repair on failure
/04 Pressure Switch	Shuts down pumps in high discharge pressure occurs	A) Bourdon tube or bellows rupture	Fails to shutdown pump, could result in line rupture	C,F,I	1×10^{10}BBL	Electrical short in wiring and circuitry; age.	Repair or replace on failure.

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13300 SHUTDOWN ONSHORE SYSTEM
ELEMENTS (2) 13310 BOOSTER PUMPING (Cont.)

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
/05 Alarm	Notifies operator of extremely low or high pressures	A) Circuitry failure	Fails to visually and audibly alert operator of significant increases or decreases in pressure	F,I	1 x 10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic testing to ensure proper working order
		B) Bulb burnout				Same as above	Same as above
		C) Horn malfunction				Same as above	Same as above
13312 Temperature Monitor							
/01 Temperature Indicator	Indicates oil temperature	A) Needle indicator stuck	False high temperature readings will result in false volume calculations and wrong pump speeds	G	1 x 10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic inspection, cleaning, and calibration
		B) Bulb breaks	Same as above	G	1 x 10^{12} BBL	Same as above	Same as above
13313 Flow Monitor							
/01 Flow Element							
13314 Flow Rate Controller							
/01 Flow Transmitter	Transmits flow rate signal to indicator	A) Circuitry failure	Could cause pump speed to vary from overspeed to stop	G,H	1 x 10^{12} BBL	Age; electrical short in wiring and circuitry	Repair or replace on failure
/05 Flow Regulator	Controls pump speed, thus maintaining desired flow rate	A) Jammed or blocked	Same as above	C,F,H	1 x 10^{12} BBL	Age; electrical short in wiring and circuitry; oil sludge blockage	Periodic inspection, cleaning, and lubrication

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13300 SHUTDOWN ONSHORE SYSTEM
ELEMENTS (2) 13310 BOOSTER PUMPING (Cont.)

EQUIPMENT IDENTIFICATION: EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EFFECTS ON: EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	SOLUTION: CORRECT ACTION RECOMMENDED (10)
/02 Flow Controller	Regulates flow rates by opening or closing valves	A) Circuitry fails	Results in flow rate fluctuations and possible controller damage	F,H	1×10^{12} BBL	Same as above	Same as above
/03 Pressure Controller	Equalizes offshore and onshore pressures	A) Circuitry fails	Same as above	F,H	1×10^{12} BBL	Same as above	Same as above
/05 Signal Selector	Compares flow rate signals from tanker and offshore pumping stations and equalizes the flow rates via the flow controller	A) Circuitry fails	Same as above	G,H	1×10^{12} BBL	Same as above	Same as above
13315 Pump Protection Devices							
/01 Level Switch	Turns off pumps if packing glands leak excessively	A) Circuitry failure	Electrical short and/or float stuck in low position will result in pumps continuing to run. Float stuck in high position will shut off pumps	C,F,I	1×10^{10} BBL*	Age; electrical short in wiring and circuitry; oil sludge blockage; corrosion; bearing failure	Periodic testing and inspection
		B) Float stuck in high or low position	Same as above	C,F,I	$(6\text{-}100) \times 10^{6}$ BBL*	Same as above	Redundant floats and/or maintenance
/02 Vibration Switch	Turns off pumps due to excess vibration	A) Circuitry failure	Excess vibrations fail to shut off pumps	E,H	1×10^{10} BBL	Oil sludge blockage; bearing failure	Periodic testing and inspection
/03 Differential Pressure Switch	Turns off pumps if low suction occurs	A) Circuitry failure	Fails to shutdown pumps; result in a line rupture and possible oil spill	E,H	1×10^{10} BBL	Low suction occurring such as when tank levels are low	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13300 SHUTDOWN ONSHORE SYSTEM
ELEMENTS (2) 13310 BOOSTER PUMPING (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/04 Air Eliminator	Bleeds off any trapped air in line before it reaches pumps	A) Float does not seal air outlet	Improper float seal will result in a minor spill	C,F,I	1×10^{12}BBL	Corrosion; sludge blockage; leaky float	Periodic inspection and cleaning
/05 Alarm	Notifies operator the pumps are either leaking, vibrating, drawing a low suction	A) Circuitry failure	Results in a short delay as the operator will not immediately be aware	F	1×10^{12}BBL	Same as above	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above	F	1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	F	1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13300 SHUTDOWN ONSHORE SYSTEM
ELEMENTS (2) 13320 PACK SYSTEM

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13321 Valve Line Up Monitor							
/01 Remote Indicator	Assures proper valve line up	A) Bulb burn-out	Delay in packing system; requires visual check	G,I	1×10^{12}BBL	Filament burnout; electrical short in wiring and circuitry; corrosion	Use test button periodically to check circuit continuities of indicator panel
		B) Circuitry failure		G,I	1×10^{12}BBL		Same as above
/02 Local Indicator	Assures proper valve line up	A) Stems on valve actuators fail to rise when valve is open	No visual confirmation of valve line up; requires manual cycling of the valves	G,H	1×10^{12}BBL	Act of nature; human error; mechanical wear; possible stem breakage	Check when locally cycling valve
13322 Valve Line Up Controller							
/01 Push Button Remote	Regulates proper valve line up	A) Button contacts worn	Delay in lining up valves, thus requiring push button local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	Upon failure, check circuit continuity and repair
		B) Circuitry failure	Same as above		1×10^{11} BBL	Same as above	Same as above
/02 Push Button Local	Regulates proper valve line up	A) Button contacts worn	Delay in lining up valves, thus requiring manual local	G,I	1×10^{11} BBL	Age; electrical short in wiring and circuitry; corrosion	Same as above
		B) Circuitry failure	Same as above		1×10^{11} BBL	Same as above	Same as above
/03 Manual Local	Regulates proper valve line up	A) Manpower unavailable to open or close valves manually	Inability to achieve line up until manpower open valves	G,H	1×10^{12} BBL	Not enough available manpower	Periodic manual cycling to ensure manual readiness
/04 Valve Actuator							
/05 Limit Switches							

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13300 SHUTDOWN ONSHORE SYSTEM
ELEMENTS (2) 13320 PACK SYSTEM (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13323 Pressure Monitor							
/01 Pressure Indicator	Denotes proper oil pressure in line	A) Needle indicator stuck	False high pressure readings will fail to completely pack onshore piping. False low pressure readings may result in overstressing and rupturing the pipeline	C,F,I	1×10^{12}BBL	Oil sludge blockage of tap; cold weather (freezing); incorrect calibration	Periodic inspection, cleaning, and calibration
		B) Bourdon tube or bellows rupture	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
		C) Other internal failure	Same as above	C,F,I	1×10^{12}BBL	Same as above	Same as above
/02 Pressure Transmitter	Transmits pressure signal to recorder	A) Circuit fails		G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Repair or replace on failure. Use redundant equipment if reliability is low
		B) Spurious signals	Same as above	G,I	1×10^{12}BBL	Same as above	Same as above
/03 Pressure Recorder	Records a pressure versus time history	A) Clock fails		G,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic inspection necessary to ensure accurate output and proper paper supply for recorder
		B) Pen or thermal print fails	Same as above	G,I	1×10^{12}BBL	Same as above	Repair on failure

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13300 SHUTDOWN ONSHORE SYSTEM
ELEMENTS (2) 13320 PACK SYSTEM (Cont.)

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
/04 Alarm	Notifies operator of extremely low or high line pressures	A) Circuitry failure	Fails to visually and audibly alert operator of significant pressure increases or decreases	C,F,I	1×10^{12}BBL	Electrical short in wiring and circuitry; age; corrosion	Periodic testing to ensure proper working order
		B) Bulb burnout	Same as above		1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above		1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13300 SHUTDOWN ONSHORE SYSTEM
ELEMENTS (2) 13330 DRAIN AND SLOPS HANDLING

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13331 Drain Tank Level Montior							
/01 Level switch	Detects high or low fluid level in drain tank.	A) Circuitry failure	Level switch stock in high position will cause unnecessary draining of drain/slops tank level switch stuck in low position may result in oil over-flow.	B	3×10^{9} BBL	Age; Electrical short in wiring and circuitry; corrosion.	Periodic testing and inspection.
		B) Float stuck in high or low postion.	Same as above	B	$(6\text{-}100) \times 10^{6}$ BBL*	Same as above	Same as above
/02 Alarm	Notifies operator of high or low fluid levels in drain tank.	A) Circuitry failure	Fails to visually and audibly alert operator of low fluid levels in drain/slop tank.	C	1×10^{12}BBL	Age; electrical short in wiring and circuitry; corrosion.	Periodic testing.
		B) Bulb burnout	Same as above	C	1×10^{12}BBL	Same as above	Same as above
		C) Horn malfunction	Same as above	C	1×10^{12}BBL	Same as above	Same as above

FAILURE MODES AND EFFECT ANALYSIS (FMEA)

SUBSYSTEM (1) 13300 SHUTDOWN ONSHORE SYSTEM
ELEMENTS (2) 13340 EMERGENCY SHUTDOWN SYSTEM

EQUIPMENT IDENTIFICATION			EFFECTS ON				SOLUTION
EQUIPMENT (3)	FUNCTION (4)	FAILURE MODE (5)	EQUIPMENT (6)	EFFECTS CATEGORIES (7)	MEAN BARRELS TO FAILURE (MBTF) (8)	CAUSE OF FAILURE (9)	CORRECT ACTION RECOMMENDED (10)
13341 Value Line Up Monitor							
/01 Remote Indicator	Assures proper line up of emergency shutdown valve.	A) Bulb burnout	It will become immediately apparent if the emergency shutdown valve closes but is not indicated at the control panel.	F	1×10^{12} BBL	Filament burnout; electrical short in wiring and circuitry; corrosion.	Use test button periodically to check circuit continuties of indicator panel.
		B) Circuitry failure	Same as above	F	1×10^{12} BBL	Same as above	Same as above
13342 Value Line Up Controller							
/01 Valve actuator	Opens or closes emergency shutdown valve.	A) Hydraulic failures	If valve fails to close when needed, a major oil spill could occur. If valve closes pre maturely a pressure shock will result with possible need for surge relief system.	A	1×10^{8} BBL	Cold weather (freezing); age; mechanical wear; mechanical seizing.	Periodic cycling and maintenance checks.
		B) Pneumatic failure		A	1×10^{8} BBL	Same as above.	Same as above
		C) Gearing or mechanical failure	Same as above	A	1×10^{10} BBL	Same as above	Same as above
13343 Valves Actuating Medium Monitor							
/01 Pressure switch	Monitors the pressure of the inert gas supply to the valve actuator-low pressure sets off alarm.	A) Circuitry failure	If no reserve supply for inert gas, then emergency shutdown valves will have to be manually cycled.	B	1×10^{10} BBL	Electrical short; age; wear.	Redandant equipment to increase reliability.
/02 Alarm	Notifies operator of low pressure in the inert gas supply.	A) Circuitry failure	Fails to visually and audibly alert operator of significant pressure increases or decreases.	B	1×10^{12} BBL	Electrical short in wiring and circuitry; age; corrosion.	Periodic testing and inspection.
		B) Bulb burnout	Same as above	B	1×10^{12} BBL	Same as above	Same as above
		C) Horn malfuntion.	Same as above	B	1×10^{12} BBL	Same as above	Same as above

APPENDIX B

ELEMENT FAULT TREES

APPENDIX B
RELIABILITY/FAULT TREE PROCEDURES

The fault tree is a comprehensive description of system failure possibilities expressed in symbolic form. The corresponding failure probabilities can be be evaluated if a basic set of failure-rate data is available and if a set of Boolean algebraic equations can be written to describe the symbolic failure relationships shown on the fault tree diagram. The data are then substituted in the ordinary algebraic equations that correspond to the failure relationships to provide a resultant numerical prediction.

To illustrate this procedure, a fault event will be developed by tracing the following major steps in the predictive technique.

- Fault tree diagram
- Equivalent algebraic equations
- Input data source
- Prediction results

The example will be taken from the Surge Relief System. The two basic operations in the fault tree are the "and" gate and the "or" gate. The Surge Relief System will fail only if the Surge Relief Availability Control fails and the Surge Relief Availability Monitor fails, and the Relief Valve Pressurization Medium Controller fails. All events under an "and" gate must fail before the event above the gate is considered failed.

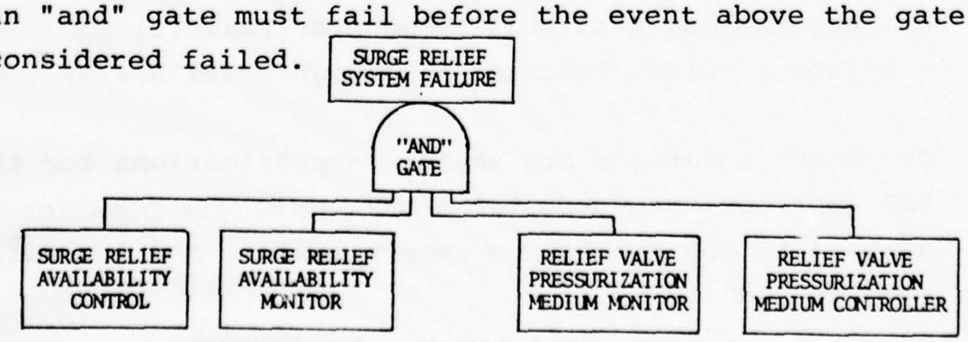


FIGURE B-1 "AND" GATE EXAMPLE

The probability of the Surge Relief System failing is:

P (Surge Relief System Failure) = P (Surge Relief Availability Control Failure) •

P (Surge Relief Availiability Monitor Failure) •

P (Relief Valve Pressurization Medium Monitor Failure) •

P (Relief Valve Pressurization Medium Controller Failure)

On the other hand, Figure B-2 is an example of an "or" gate. The Surge Relief Availiability Monitor will fail if the Level Switch fails or the High Level Alarm fails. .Any event which fails under an "or" gate will cause the event above the gate to fail.

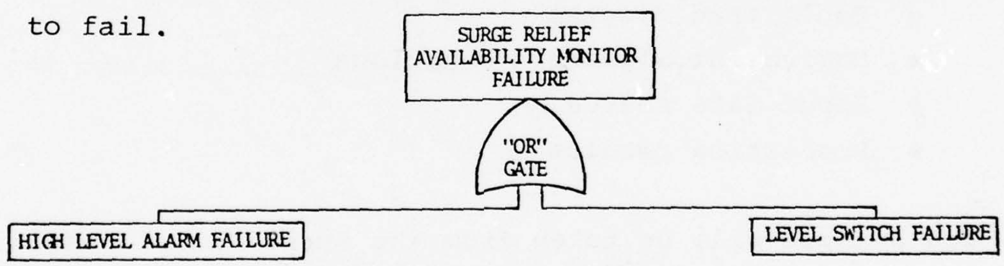


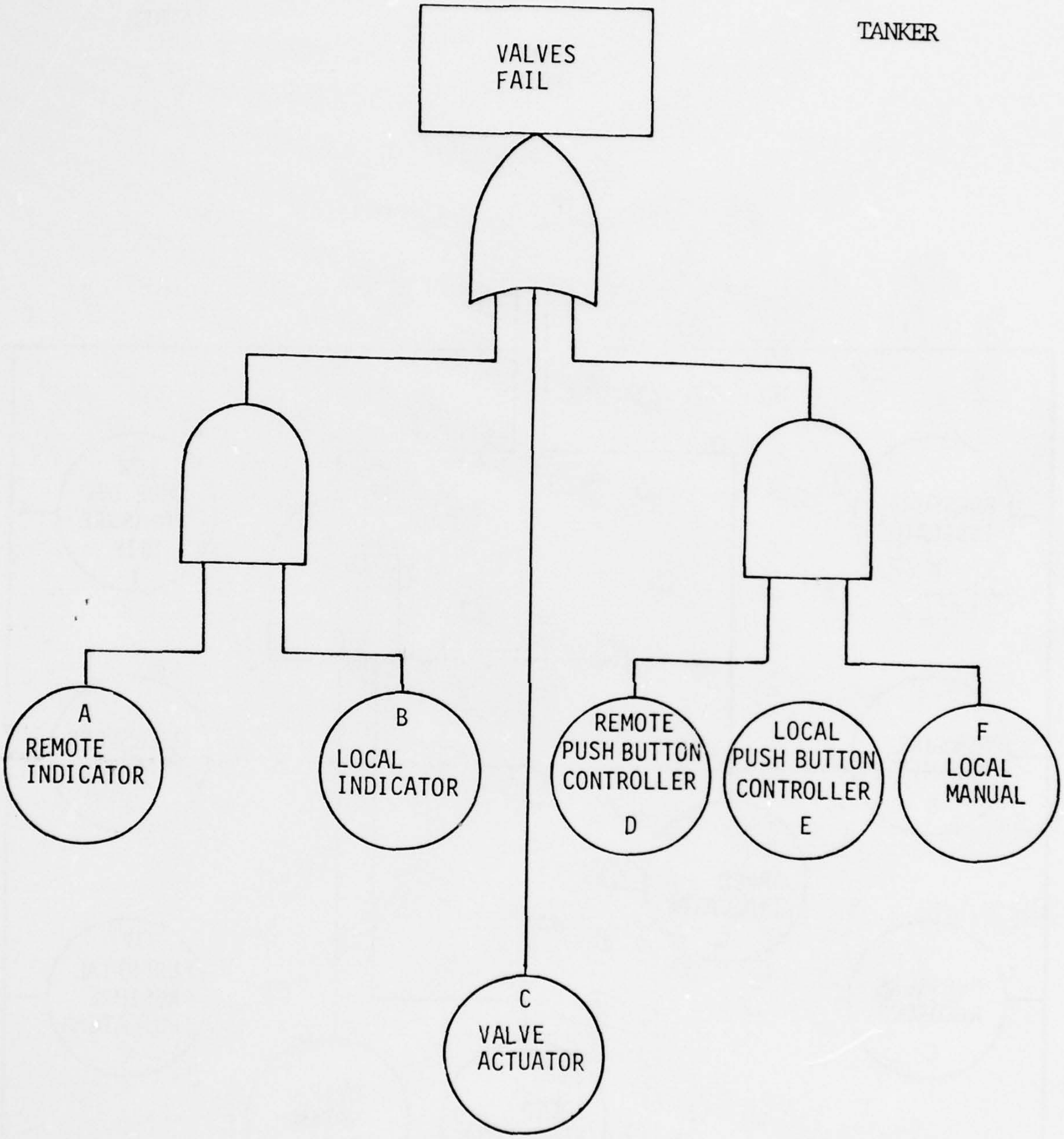
FIGURE B-2 "OR" GATE EXAMPLE

The probability of the Surge Relief Availability Monitor failing is:

P (Surge Relief Availability Monitor Failure)
= P (Level Switch Failure) + P (High Level Alarm)

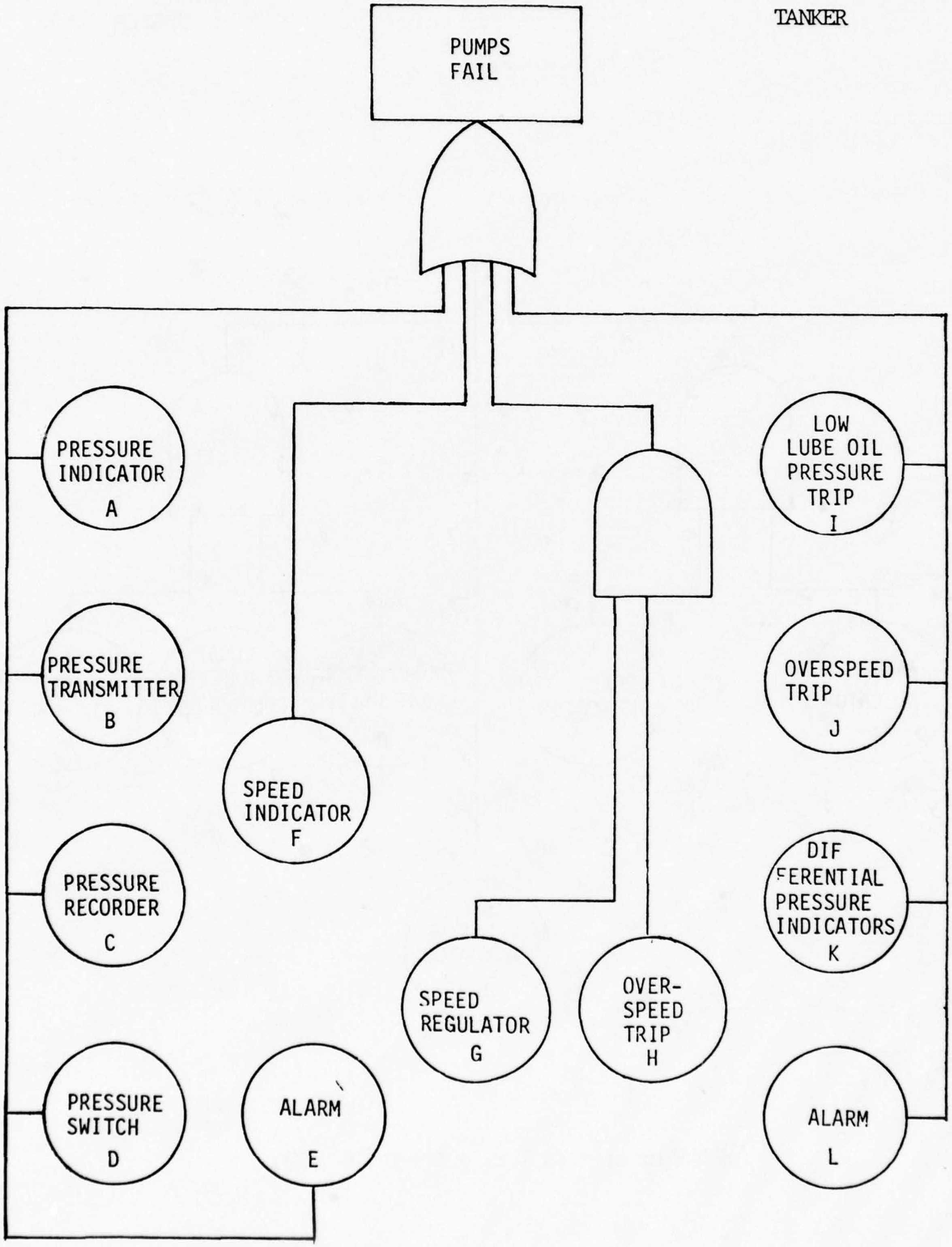
The above equations are useful approximations for the specific DWP applications where the exponential distribution is assumed to approximate equipment failure and the failure rates are less and 10^{-4}.

TANKER



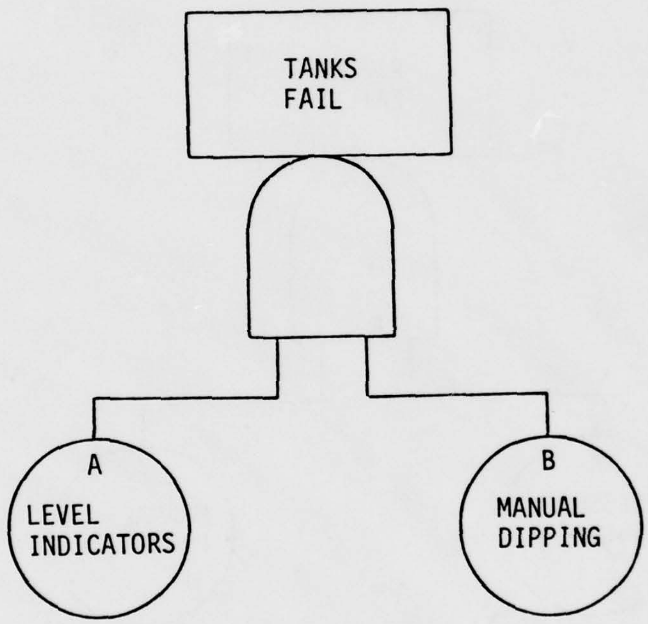
$$P(\text{failure}) = (A \cdot B) + C + (D \cdot E \cdot F)$$

TANKER



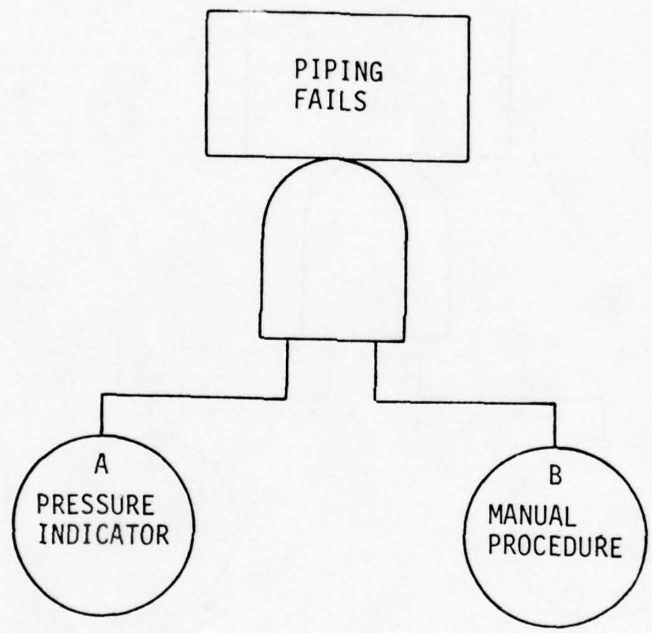
$$P(\text{failure}) = A + B + C + D + E + F + (G \cdot H) + I + J + K + L$$

TANKER



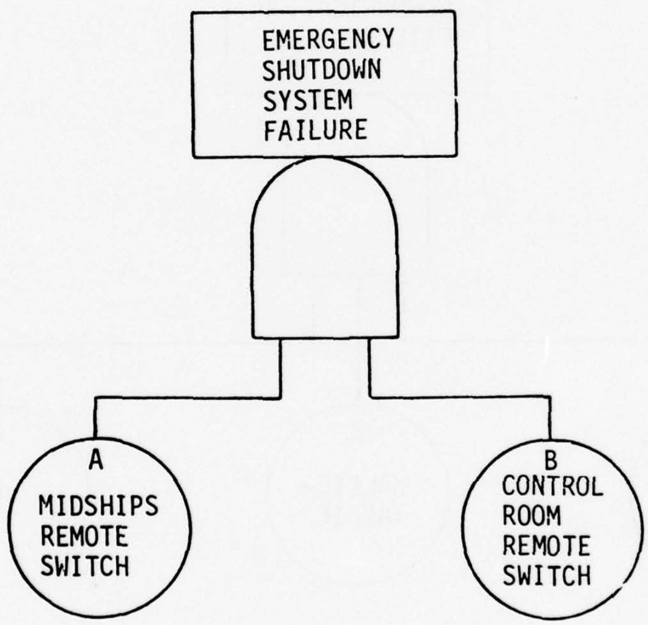
$$P(\text{failure}) = A \cdot B$$

TANKER



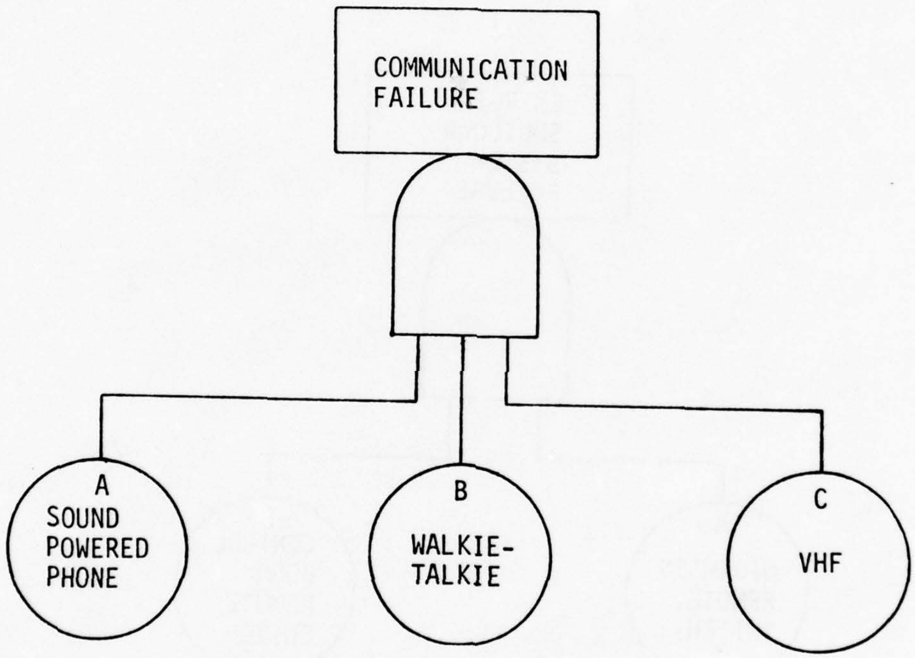
P(failure) = A . B

TANKER



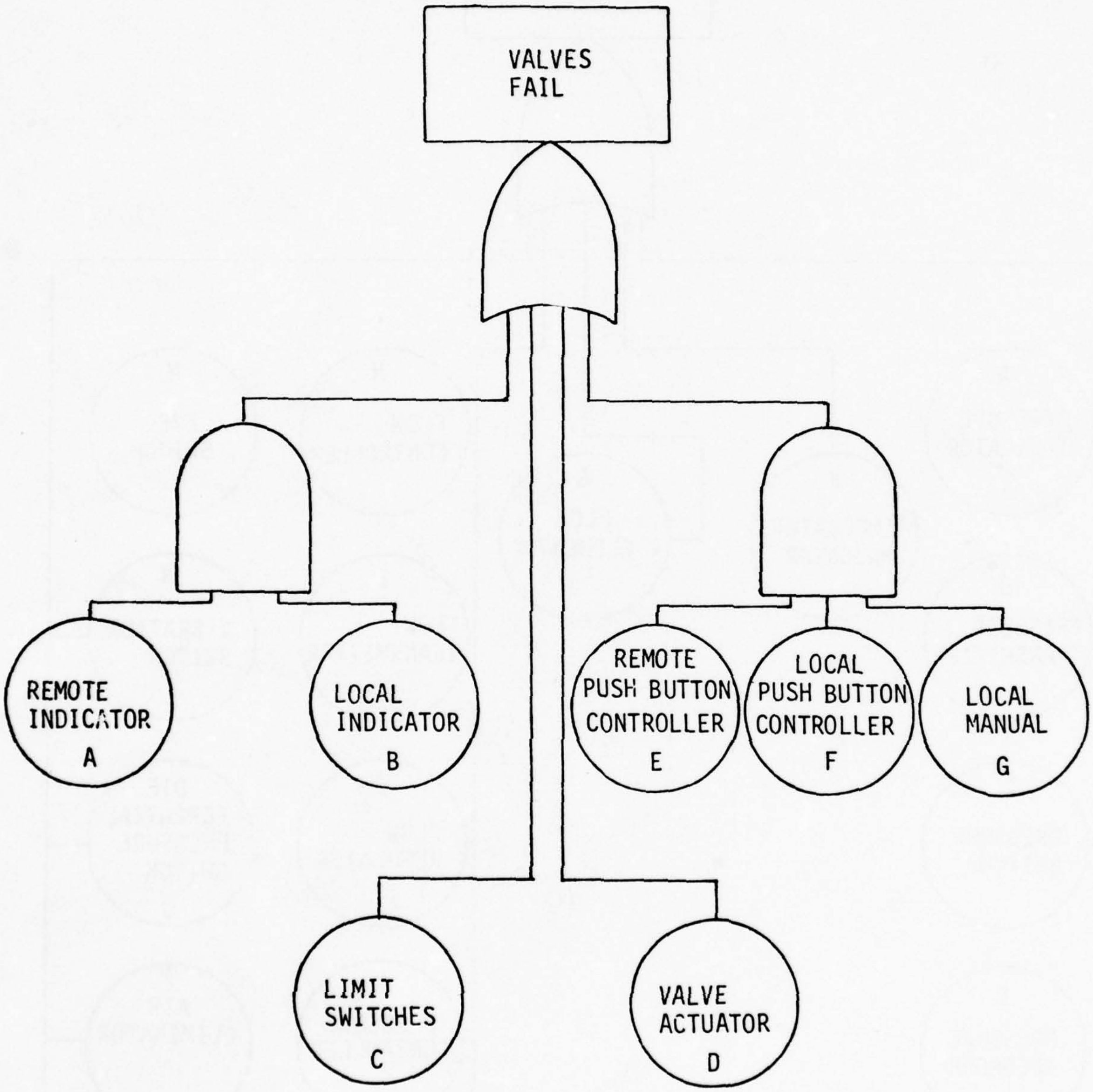
$P(\text{failure}) = A \cdot B$

TANKER



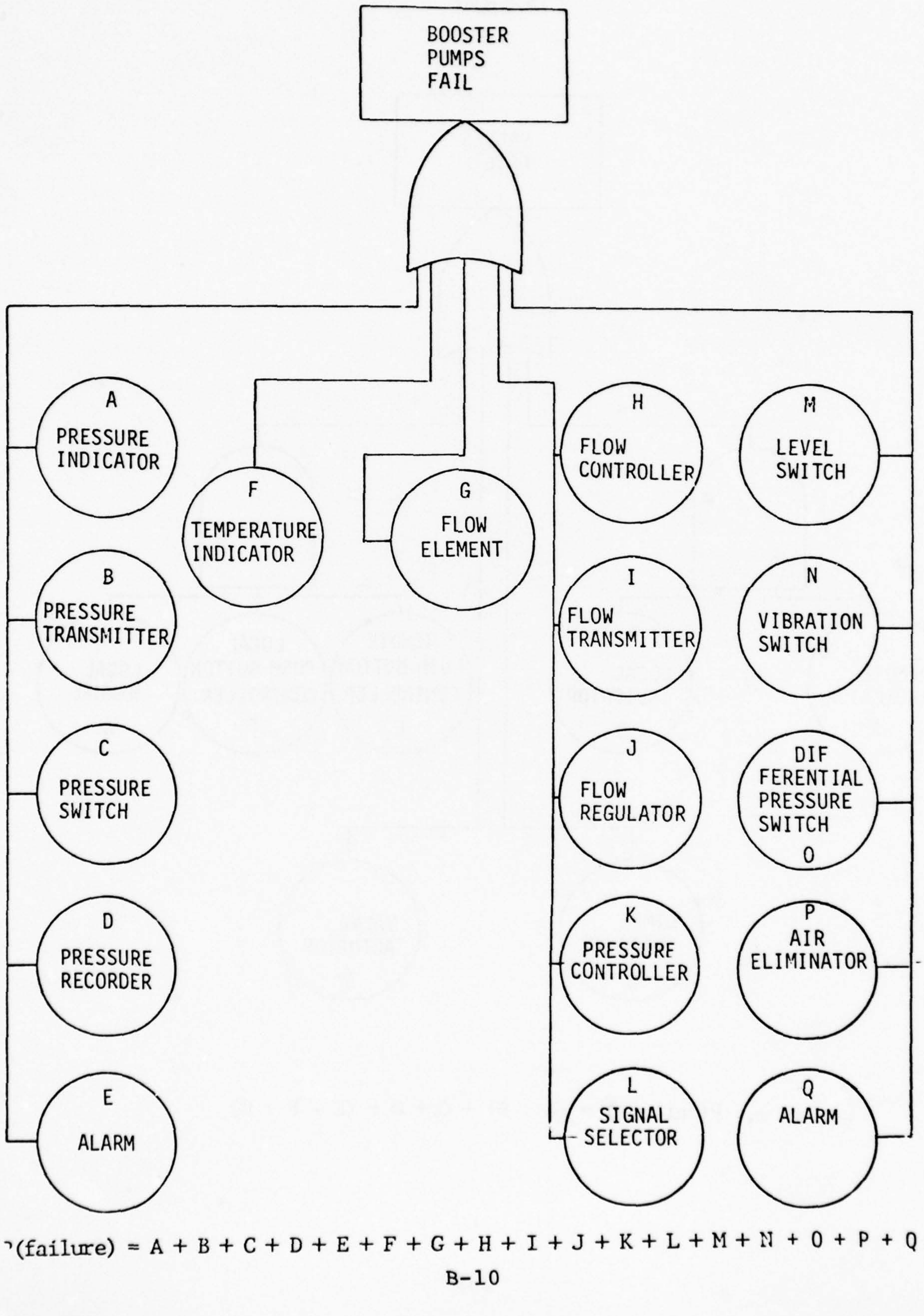
P(failure) = A · B · C

OFFSHORE



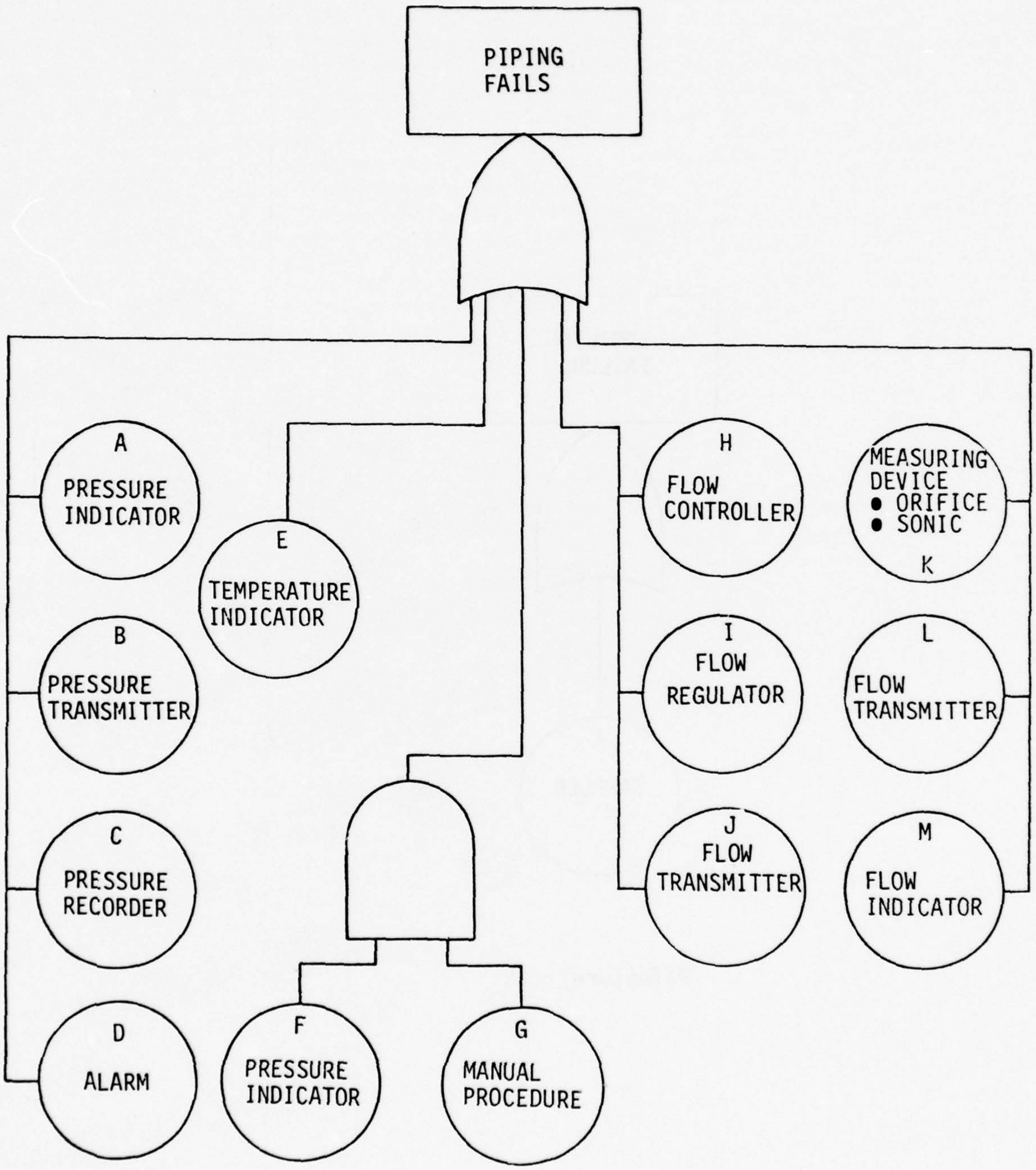
$$P(\text{failure}) = (A \cdot B) + C + D + (E \cdot F \cdot G)$$

OFFSHORE



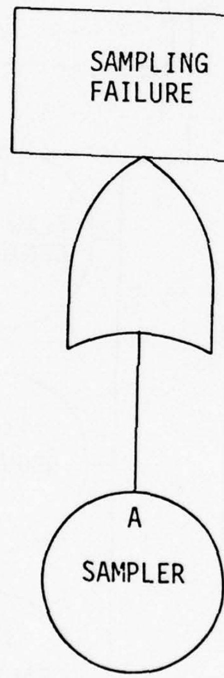
P(failure) = A + B + C + D + E + F + G + H + I + J + K + L + M + N + O + P + Q

OFFSHORE



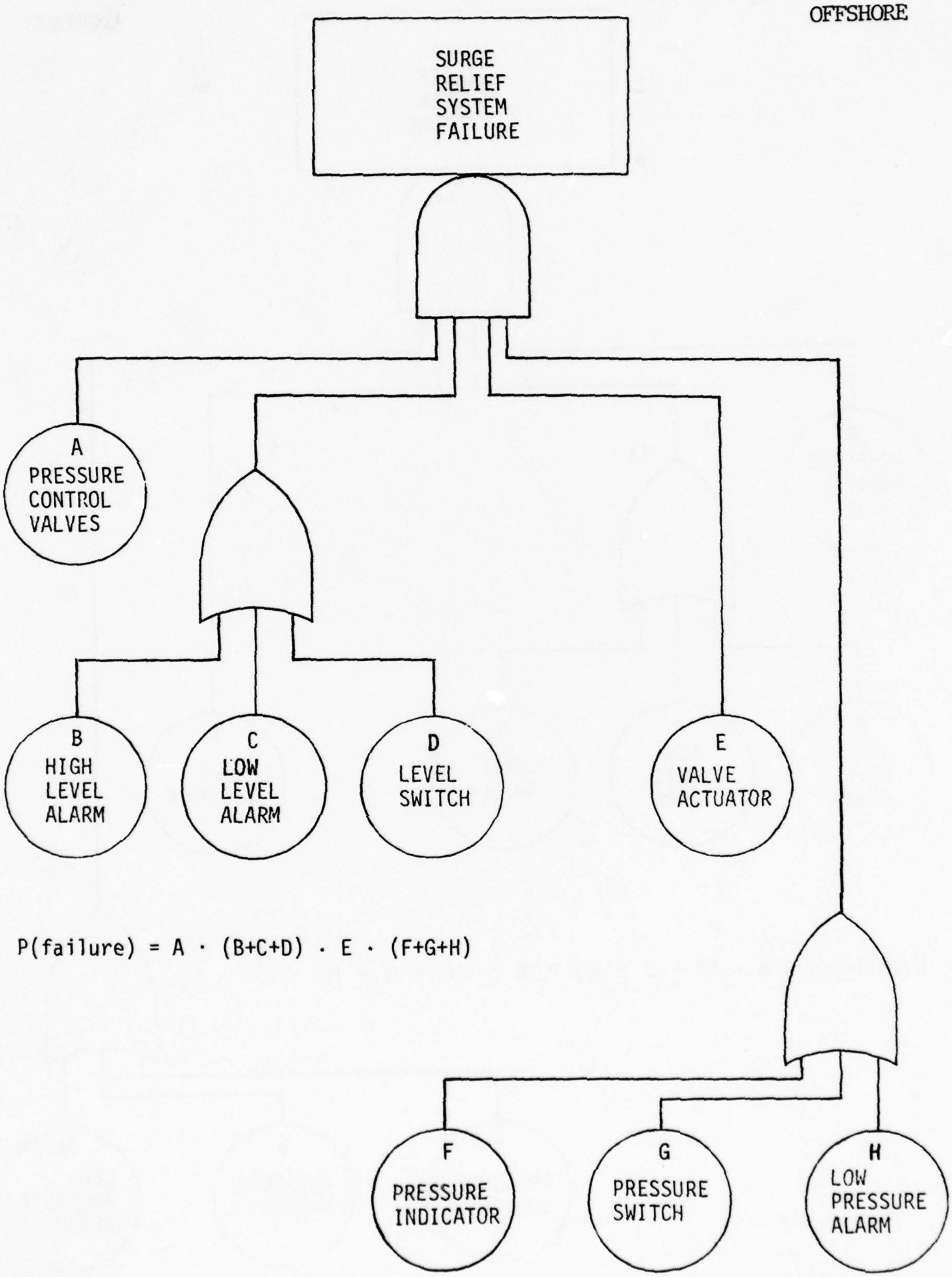
$$P(\text{failure}) = A + B + C + D + E + (F \cdot G) + H + I + J + K + L + M$$

OFFSHORE



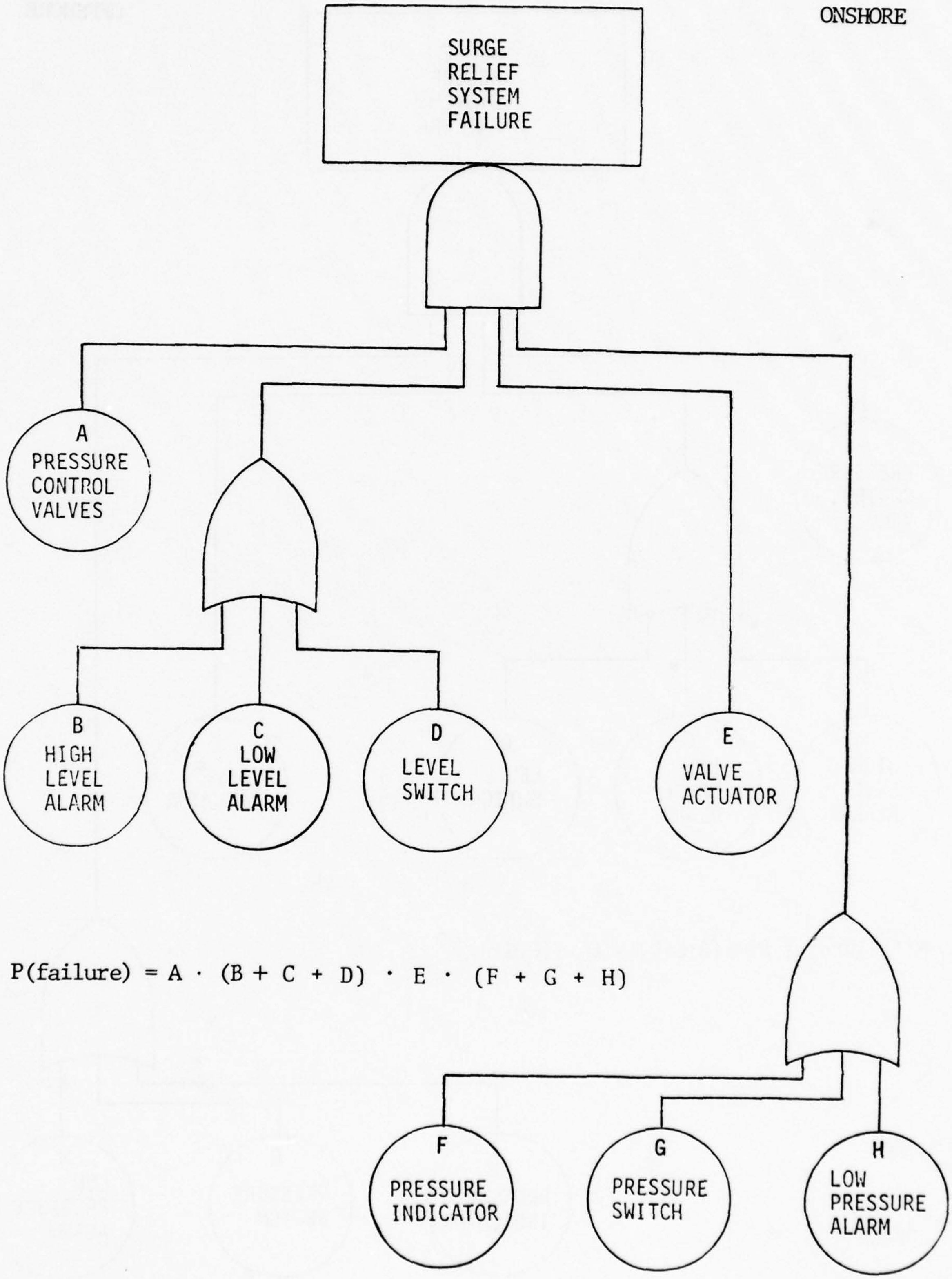
P(failure) = A

OFFSHORE



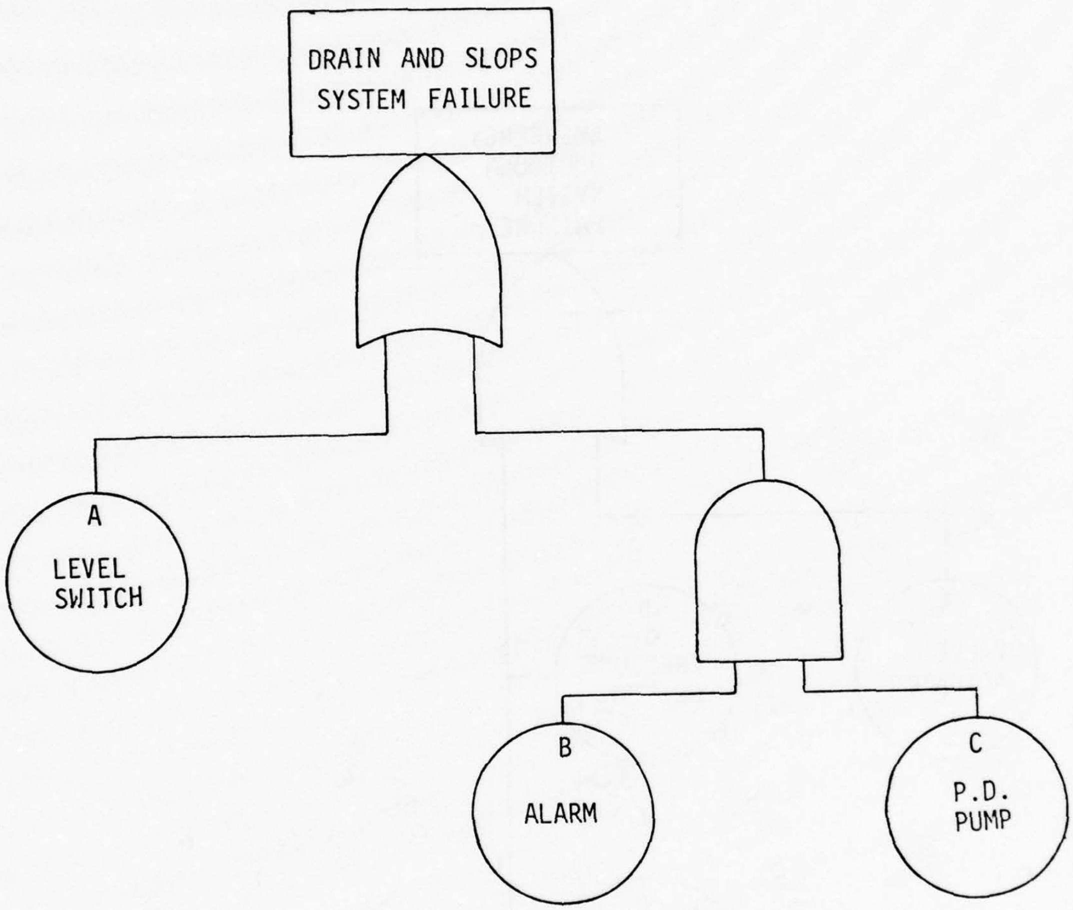
$$P(\text{failure}) = A \cdot (B+C+D) \cdot E \cdot (F+G+H)$$

ONSHORE



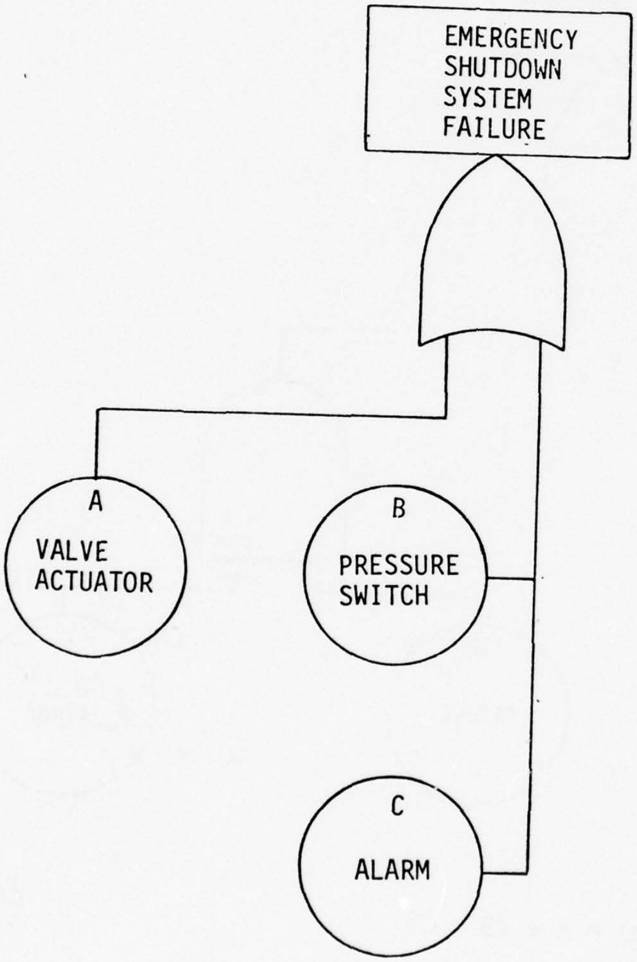
$$P(\text{failure}) = A \cdot (B + C + D) \cdot E \cdot (F + G + H)$$

OFFSHORE



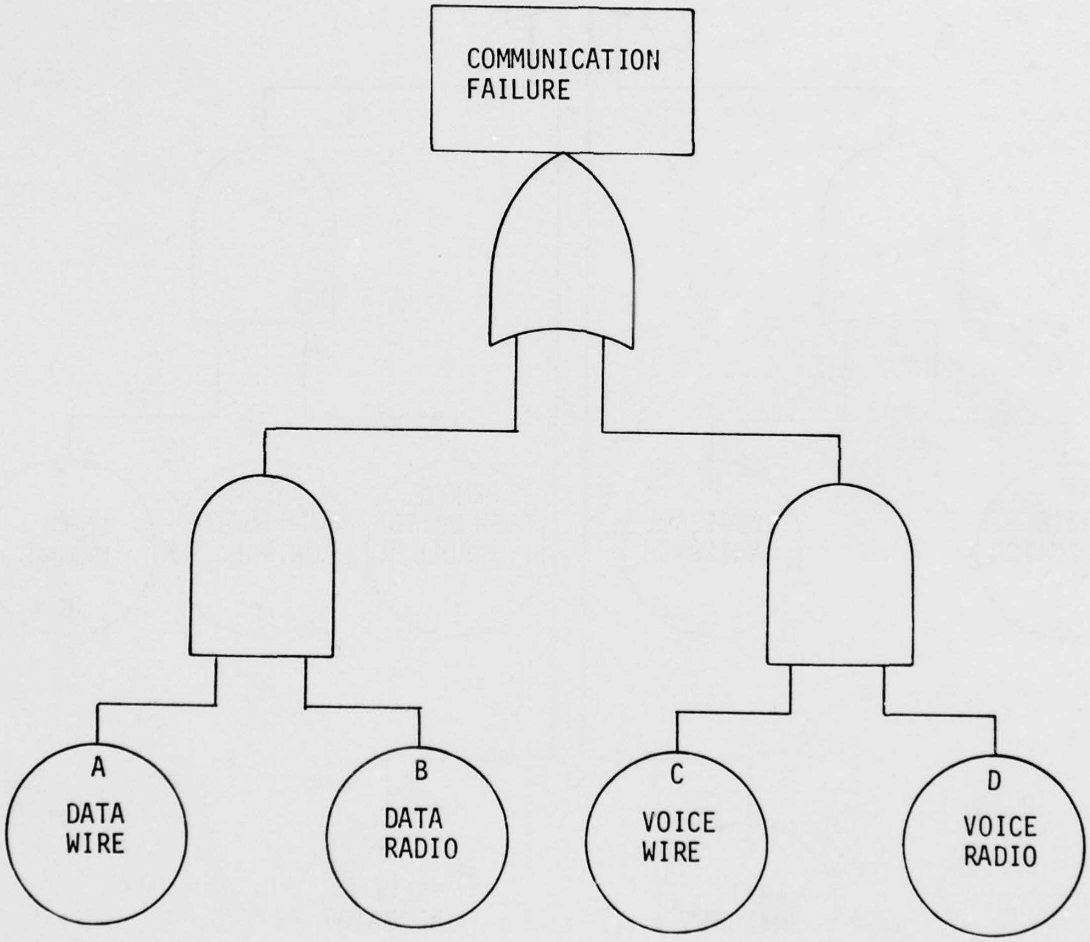
$$P(\text{failure}) = A + (B \cdot C)$$

OFFSHORE



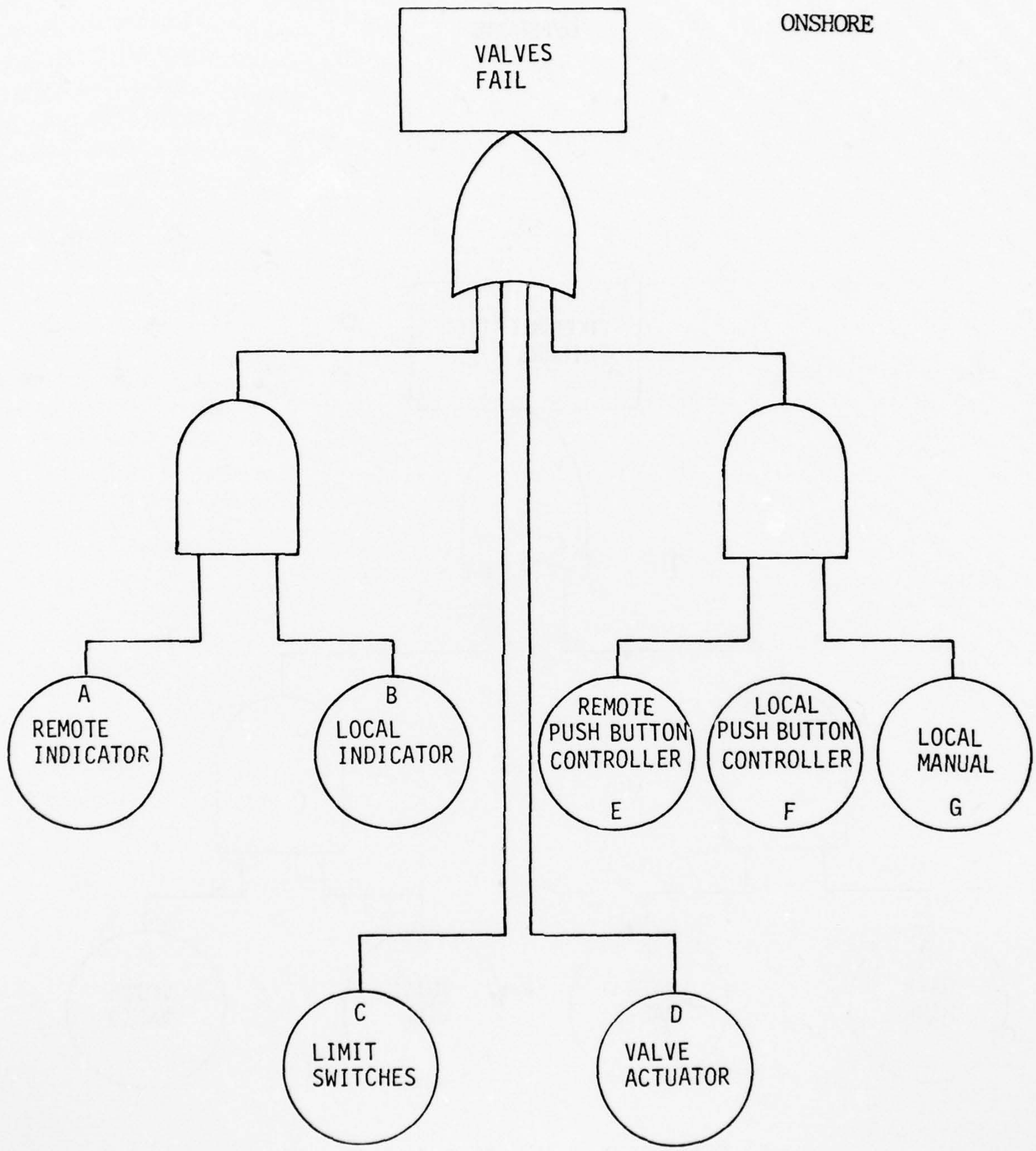
P(failure) = A + B + C

OFFSHORE

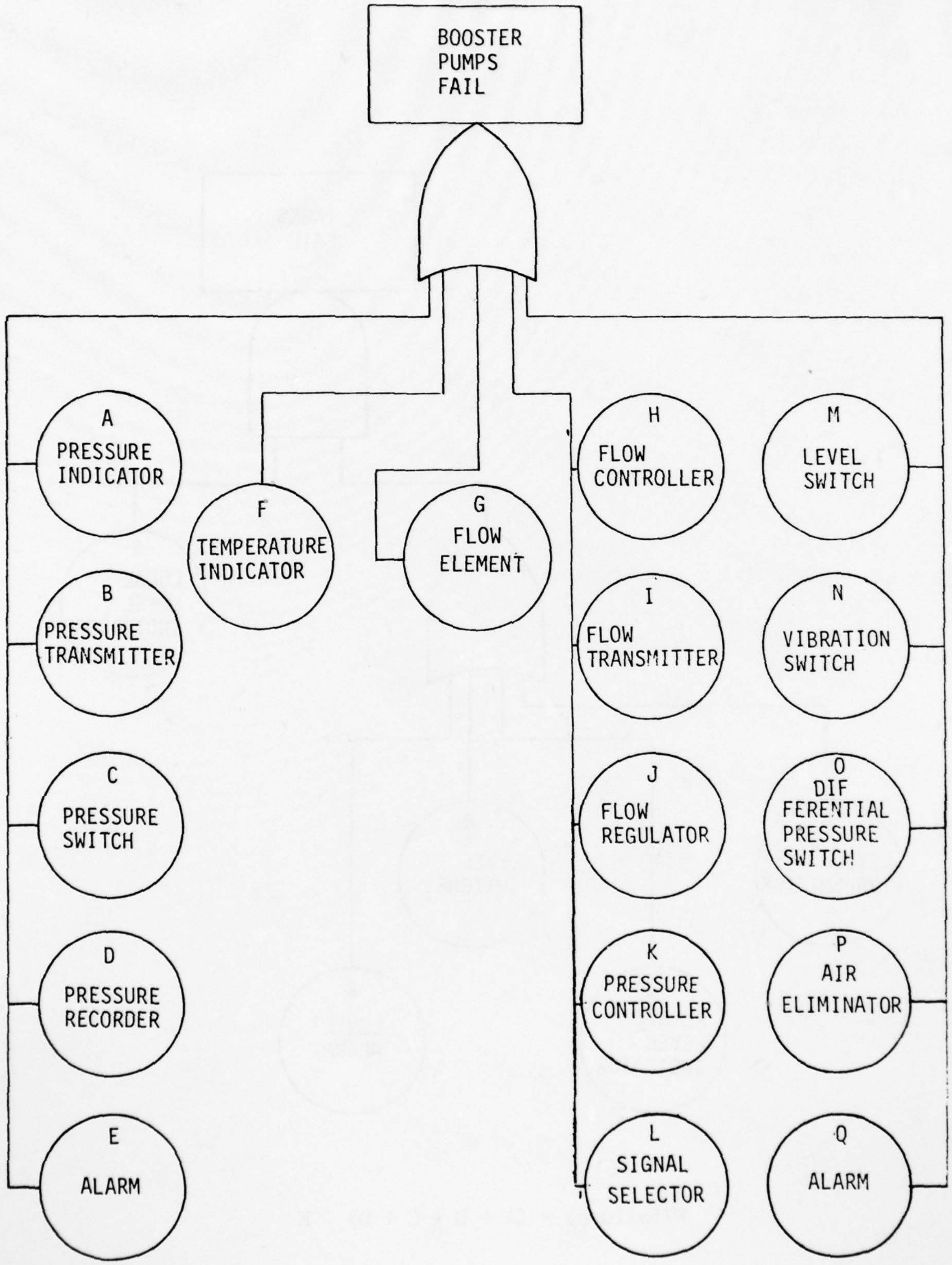


P(failure) = (A · B) + (C · D)

ONSHORE

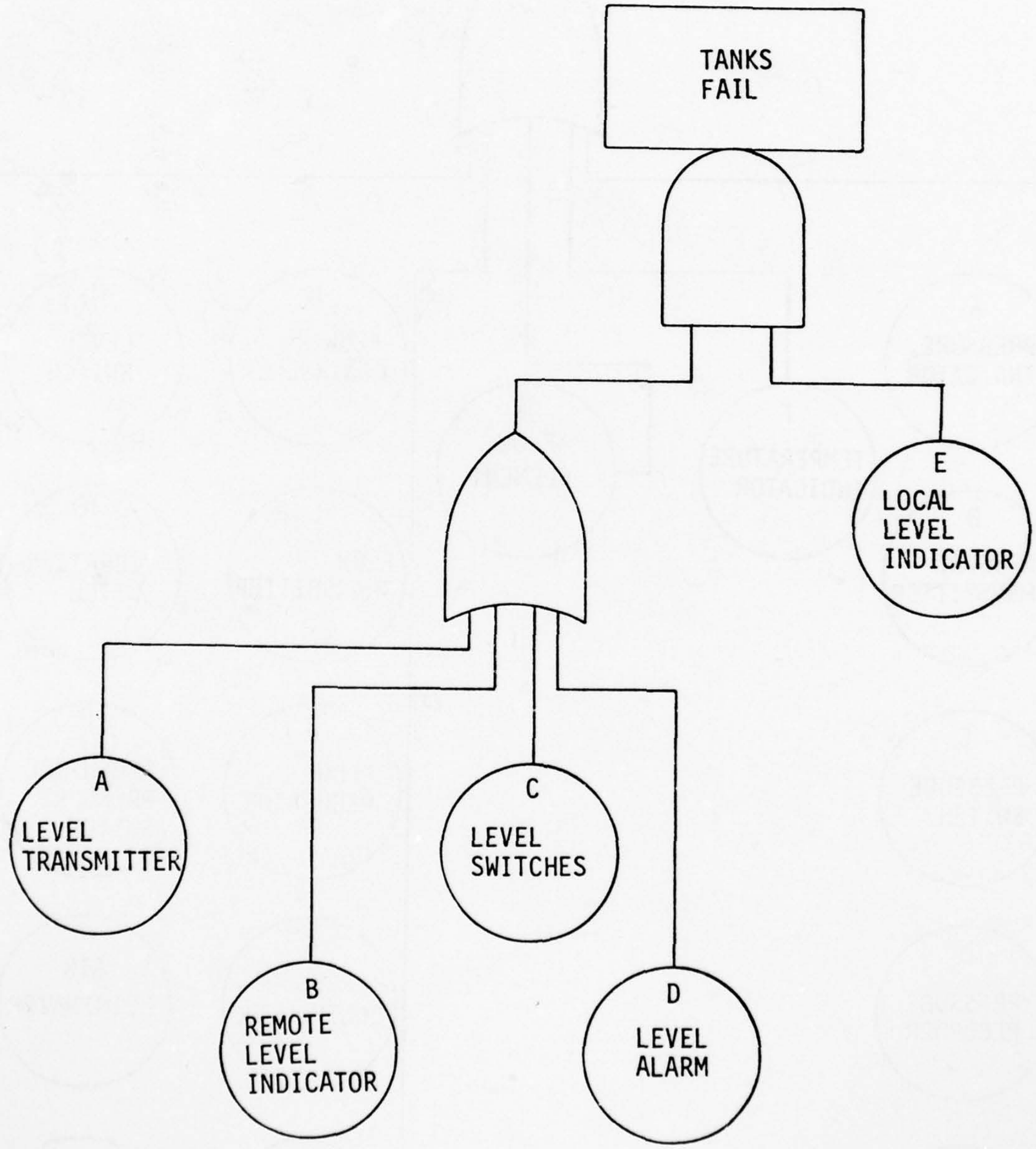


$$P(\text{failure}) = (A \cdot B) + C + D + (E \cdot F \cdot G)$$



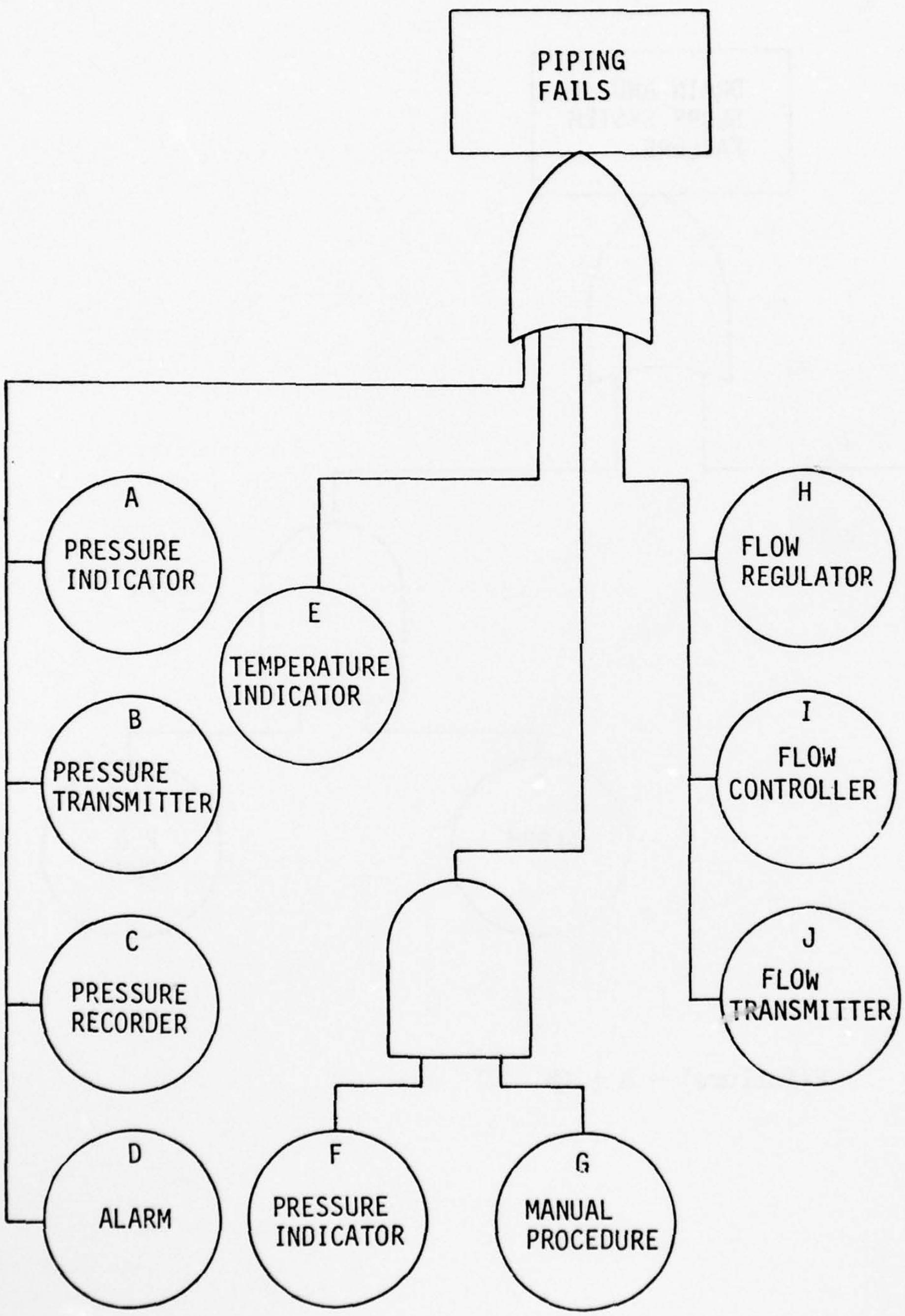
P(failure) = A + B + C + D + E + F + G + H + I + J + K + L + N + O + P + Q

ONSHORE



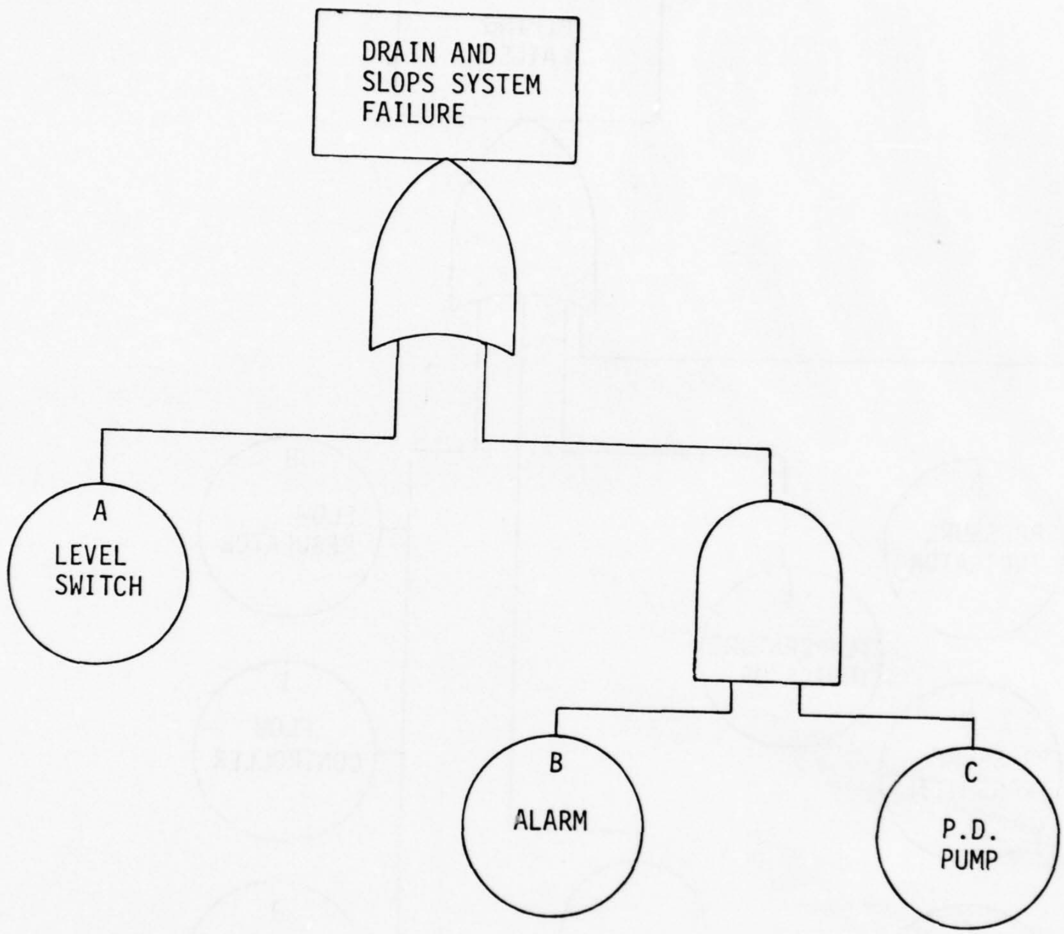
$$P(\text{failure}) = (A + B + C + D) \cdot E$$

ONSHORE



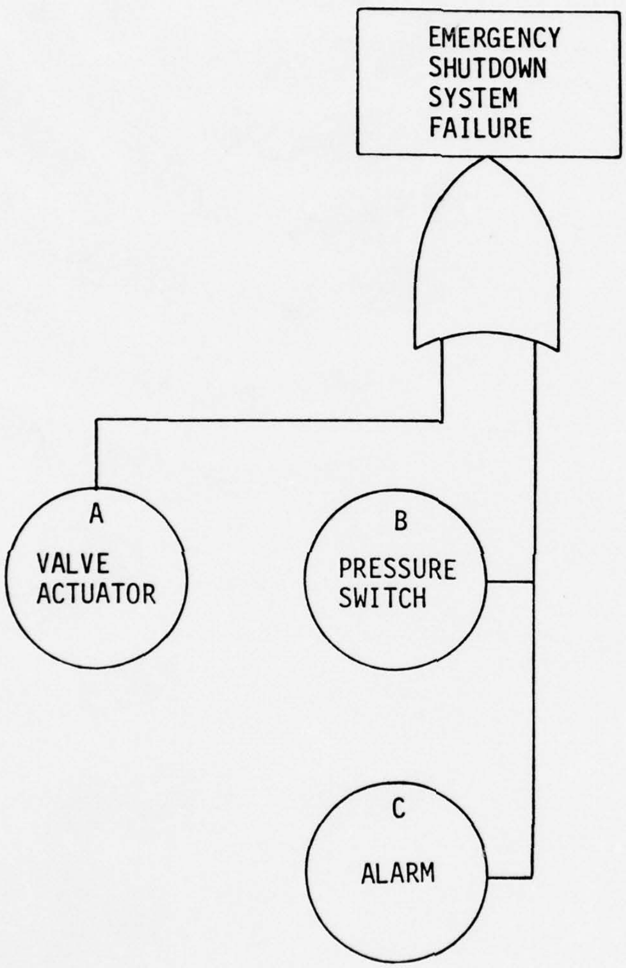
$$P(\text{failure}) = A + B + C + D + E + (F \cdot G) + H + I + J$$

ONSHORE



P(failure) = A + (B · C)

ONSHORE



$$P(\text{failure}) = A + B + C$$

APPENDIX C

ELEMENT RELIABILITY/EFFECTS RATING SHEET

ELEMENT DESCRIPTION TANKER VALVES

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
11111, 11223, 11341						
/01 Remote Indicator	10^{-12}	10^{-12}	4	.083	8.3×10^{-14}	8.3×10^{-14}
/02 Local Indicator	10^{-12}	10^{-12}	6	.125	1.25×10^{-13}	1.25×10^{-13}
1112, 11222, 11342						
/01 Push Button Remote	10^{-11}	10^{-12}	4	.083	8.3×10^{-13}	8.3×10^{-14}
/02 Push Button Local	10^{-11}	10^{-12}	4	.083	8.3×10^{-13}	8.3×10^{-14}
/03 Manual Local	10^{-12}	10^{-12}	6	.125	1.25×10^{-13}	1.25×10^{-13}
/04 Valve Actuator	10^{-8}	10^{-12}	12	.25	2.5×10^{-9}	2.5×10^{-13}
/05 Limit Switches	10^{-12}	10^{-12}	12	.25	2.5×10^{-13}	2.5×10^{-13}
			$\sum F_i = 48$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.5×10^{-13}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.5×10^{-13}

NORMALIZED ELEMENT RELIABILITY RATING $\{1-[(9)\div(8)]\}$ 1.0*

*100% Reliable

ELEMENT DESCRIPTION TANKER PUMPS

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
11211, 11311						
/01 Pressure Indicator	10^{-12}	10^{-12}	18	.129	1.29×10^{-13}	1.29×10^{-13}
/02 Pressure Transmitter	10^{-12}	10^{-12}	4	.029	2.9×10^{-14}	2.9×10^{-14}
/03 Pressure Recorder	10^{-12}	10^{-12}	4	.029	2.9×10^{-14}	2.9×10^{-14}
/04 Pressure Switch	10^{-10}	10^{-12}	18	.129	1.29×10^{-11}	1.29×10^{-13}
/05 Alarm	10^{-12}	10^{-12}	18	.129		1.29×10^{-13}
11212, 11312						
/01 Speed Indicator	10^{-8}	10^{-12}	1	.007	7×10^{-11}	7.0×10^{-15}
/02 Speed Regulator	10^{-12}	10^{-12}	20	.144	1.44×10^{-13}	1.44×10^{-13}
11213, 11313						
/01 Overspeed Trip	10^{-10}	10^{-12}	14	.101	1.01×10^{-11}	1.01×10^{-13}
			$\sum F_i =$ cont			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ________

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ________

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ ________

ELEMENT DESCRIPTION TANKER PUMPS (CON'T.)

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
62 Temperature SWITCH	10^{-10}	10^{-12}	14	.101	1.01×10^{-11}	1.01×10^{-13}
63 LOW LUBE PRESSURE SWITCH	10^{-10}	10^{-12}	14	.101	1.01×10^{-11}	1.01×10^{-13}
64 ALARM	10^{-10}	10^{-12}	14	.101	1.01×10^{-11}	1.01×10^{-13}
			$\sum F_i = 139$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 5.35×10^{-11}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 8.56×10^{-13}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .984

ELEMENT DESCRIPTION TANKER TANKS

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
11221						
01 LEVEL INDICATOR	10^{-12}	10^{-12}	4	.4	4.0×10^{-13}	4.0×10^{-13}
02 MANUAL DIPPING	10^{-12}	10^{-12}	6	.6	6.0×10^{-13}	6.0×10^{-13}
			$\sum F_i$ = 10			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.4×10^{-25}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.4×10^{-25}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ 1.0 *

* 100% Reliable

ELEMENT DESCRIPTION TANKER PIPING

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
11321						
/01 Pressure Indicator	10^{-12}	10^{-12}	18	.818	8.18×10^{-13}	8.18×10^{-13}
11322						
/01 Manual Procedure	4×10^{-8}	10^{-12}	4	.182	7.28×10^{-9}	1.82×10^{-13}
			$\sum F_i = 22$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 5.95×10^{-21}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 1.48×10^{-25}

NORMALIZED ELEMENT RELIABILITY RATING $\left| 1 - \left[(9) \div (8) \right] \right|$ .999

ELEMENT DESCRIPTION TANKER EMERGENCY SHUTDOWN SYSTEM

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
11330						
01 MIDSHIPS REMOTE PUMP SHUTDOWN SWITCH	10^{-10}	10^{-12}	24	.5	5×10^{-11}	5×10^{-13}
02 CONTROL ROOM REMOTE PUMP SHUTDOWN SWITCH	10^{-10}	10^{-12}	24	.5	5×10^{-11}	5×10^{-13}
			$\sum F_i$ = 48			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.5×10^{-21}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.5×10^{-25}

NORMALIZED ELEMENT RELIABILITY RATING $\left| 1 - \left[(9) \div (8) \right] \right|$ 0.999

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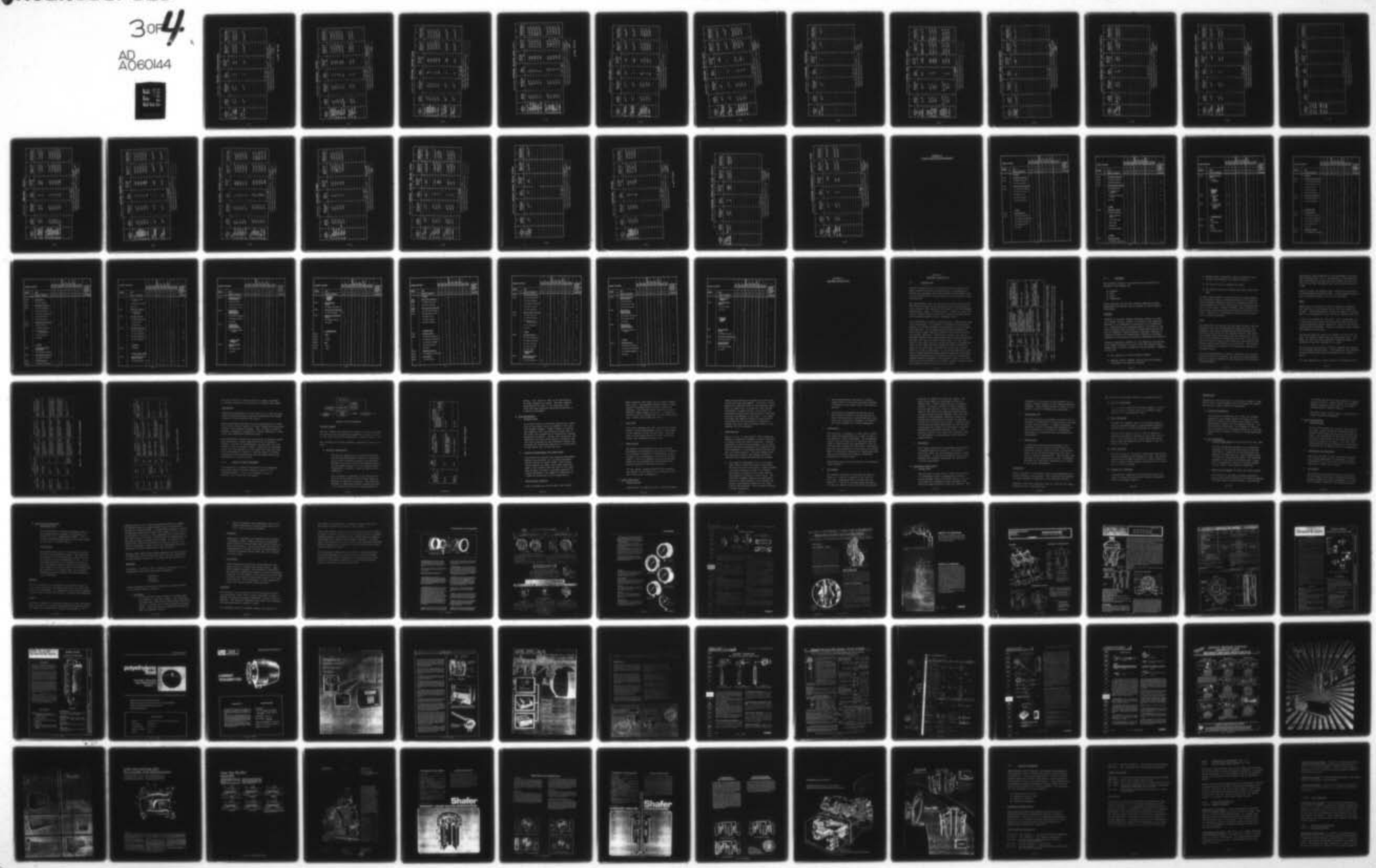

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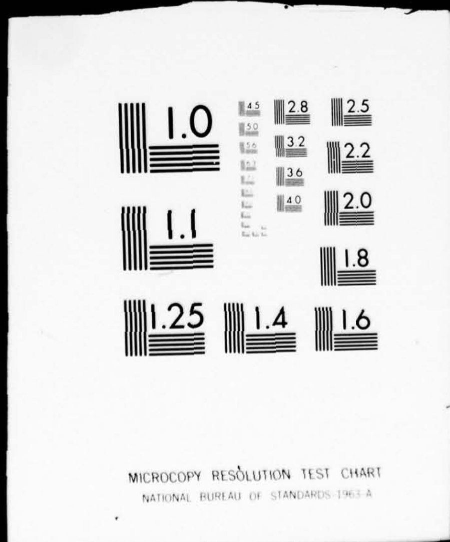


ELEMENT DESCRIPTION TANKER COMMUNICATIONS

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
11410						
~~01~~ VHF	10^{-12}	10^{-12}	4	.33	3.33×10^{-13}	3.33×10^{-13}
~~02~~ "WALKIE-TALKIE"	10^{-12}	10^{-12}	4	.33	3.33×10^{-13}	3.33×10^{-13}
11420						
01 SP PHONE	10^{-12}	10^{-12}	4	.33	3.33×10^{-13}	3.33×10^{-13}
			$\sum F_i = 12$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 3.69×10^{-38}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 3.69×10^{-38}

NORMALIZED ELEMENT RELIABILITY RATING $|1 - [(9) + (8)]|$ 1.0*

*100% Reliable

ELEMENT DESCRIPTION OFFSHORE VALVES

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12121, 12321						
/01 PUSH BUTTON REMOTE	10^{-11}	10^{-12}	4	.071	7.1×10^{-13}	7.1×10^{-14}
/02 PUSH BUTTON LOCAL	10^{-11}	10^{-12}	4	.071	7.1×10^{-13}	7.1×10^{-14}
/03 MANUAL LOCAL	10^{-12}	10^{-12}	6	.107	1.07×10^{-13}	1.07×10^{-13}
/04 VALVE ACTUATOR	10^{-8}	10^{-12}	12	.214	2.14×10^{-9}	2.14×10^{-13}
/05 LIMIT SWITCHES	3.3×10^{-10}	10^{-12}	20	.357	1.19×10^{-10}	3.5×10^{-13}
12122, 12321						
/01 REMOTE INDICATOR	10^{-12}	10^{-12}	4	.071	7.1×10^{-14}	7.1×10^{-14}
/02 LOCAL INDICATOR	10^{-12}	10^{-12}	6	.107	1.07×10^{-13}	1.07×10^{-13}
			$\sum F_i = 56$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.259×10^{-9}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 5.64×10^{-13}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .999

ELEMENT DESCRIPTION OFFSHORE BOOSTER PUMPS

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12231, 12311						
/01 PRESSURE INDICATOR	10^{-12}	10^{-12}	18	.093	9.3×10^{-14}	9.3×10^{-14}
/02 PRESSURE TRANSMITTER	10^{-12}	10^{-12}	4	.021	2.1×10^{-14}	2.1×10^{-14}
/03 PRESSURE RECORDER	10^{-12}	10^{-12}	4	.021	2.1×10^{-14}	2.1×10^{-14}
/04 PRESSURE SWITCH	10^{-10}	10^{-12}	10	.052	5.2×10^{-12}	5.2×10^{-14}
/05 ALARM	10^{-12}	10^{-12}	18	.093	9.3×10^{-14}	9.3×10^{-14}
12232, 12312						
/01 TEMPERATURE INDICATOR	10^{-12}	10^{-12}	1	.005	5.0×10^{-15}	5.0×10^{-15}
12233, 12313						
/01 FLOW ELEMENT	10^{-12}	10^{-12}	14	.072	7.2×10^{-14}	7.2×10^{-14}
			$\sum F_i$ = (CONT'.)			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ____________

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ____________

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ ____________

ELEMENT DESCRIPTION OFFSHORE BOOSTER PUMPS (CONT.)

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12234, 12314						
/01 FLOW TRANSMITTER	10^{-12}	10^{-12}	12	.062	6.2×10^{-14}	6.2×10^{-14}
/02 FLOW CONTROLLER	10^{-12}	10^{-12}	12	.062	6.2×10^{-14}	6.2×10^{-14}
/03 PRESSURE CONTROLLER	10^{-12}	10^{-12}	12	.062	6.2×10^{-14}	6.2×10^{-14}
/04 SIGNAL SELECTOR	10^{-12}	10^{-12}	6	.031	3.1×10^{-14}	3.1×10^{-14}
/05 FLOW REGULATOR	10^{-12}	10^{-12}	12	.062	6.2×10^{-14}	6.2×10^{-14}
12235, 12315						
/01 LEVEL SWITCH	10^{-10}	10^{-12}	18	.093	9.3×10^{-11}	9.3×10^{-14}
/02 VIBRATION SWITCH	10^{-4}	10^{-12}	14	.072	7.2×10^{-6}	7.2×10^{-14}
/03 DIFFERENTIAL PRESSURE SWITCH	10^{-4}	10^{-12}	14	.072	7.2×10^{-6}	7.2×10^{-14}
/04 AIR ELIMINATOR	10^{-6}	10^{-12}	18	.093	9.3×10^{-8}	9.3×10^{-14}
/05 ALARM	10^{-12}	10^{-12}	7	.036	3.6×10^{-14}	3.6×10^{-14}
			$\sum F_i = 194$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 1.45×10^{-5}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 1.00×10^{-12}

NORMALIZED ELEMENT RELIABILITY RATING $\left| 1 - \left[(9) \div (8) \right] \right|$ 1.0*

* 100% Reliable

ELEMENT DESCRIPTION OFFSHORE PIPING

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12111						
01 Pressure Indicator	10^{-12}	10^{-12}	20	.168	1.68×10^{-13}	1.68×10^{-13}
12112						
01 Hose Loading Arm/Manual Procedure	10^{-12}	10^{-12}	6	.050	5.0×10^{-14}	5.0×10^{-14}
12211						
01 Pressure Indicator	10^{-12}	10^{-12}	18	.151	1.5×10^{-13}	1.5×10^{-13}
02 Pressure Transmitter	10^{-12}	10^{-12}	4	.033	3.3×10^{-14}	3.3×10^{-14}
03 Pressure Recorder	10^{-12}	10^{-12}	4	.033	3.3×10^{-14}	3.3×10^{-14}
04 Alarm	10^{-12}	10^{-12}	18	.151	1.51×10^{-13}	1.51×10^{-13}
			$\sum F_i$ = (CONT)			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ______

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ______

NORMALIZED ELEMENT RELIABILITY RATING $\left| 1 - \left[(9) \div (8) \right] \right|$ ______

ELEMENT DESCRIPTION OFFSHORE PIPING (CONT)

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12212						
/01 Temperature Indicator	10^{-12}	10^{-12}	1	.008	8.0×10^{-15}	8.0×10^{-15}
12213						
/01 Measuring Device	10^{-8}	10^{-12}	12	.1	1.0×10^{-9}	1.0×10^{-13}
12214						
/01 FLOW INDICATOR	10^{-12}	10^{-12}	6	.050	5.0×10^{-14}	5.0×10^{-14}
/02 FLOW CONTROLLER	10^{-12}	10^{-12}	12	.1	1.0×10^{-13}	1.0×10^{-13}
/03 FLOW TRANSMITTER	10^{-12}	10^{-12}	6	.050	5.0×10^{-14}	5.0×10^{-14}
/04 FLOW REGULATOR	10^{-12}	10^{-12}	12	.1	1.0×10^{-13}	1.0×10^{-13}
			$\sum F_i = 119$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 1.00×10^{-9}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 7.75×10^{-13}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .999

ELEMENT DESCRIPTION OFFSHORE SAMPLING

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12220						
/01 SAMPLER	10^{-10}	10^{-12}	1	1	10^{-10}	10^{-12}
			$\sum F_i =$ 1			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 10^{-10}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 10^{-12}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .99

ELEMENT DESCRIPTION OFFSHORE SURGE RELIEF SYSTEM.

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12241						
/01 Valve Actuator	10^{-8}	10^{-12}	24	.358	3.58×10^{-9}	3.58×10^{-13}
12242						
/01 Level Switch	10^{-12}	10^{-12}	6	.090	9.0×10^{-14}	9.0×10^{-14}
/02 High Level Alarm	10^{-12}	10^{-12}	6	.090	9.0×10^{-14}	9.0×10^{-14}
/03 Low level Alarm	10^{-12}	10^{-12}	1	.090	1.5×10^{-14}	1.5×10^{-14}
12243						
/01 Pressure Indicator	6×10^{-12}	6×10^{-12}	1	.015	9.0×10^{-14}	9.0×10^{-14}
/02 Pressure Switch	10^{-12}	10^{-12}	7	.104.	1.04×10^{-13}	1.04×10^{-13}
/03 Alarm.	10^{-12}	10^{-12}	7	.104	1.04×10^{-13}	1.04×10^{-13}
			$\sum F_i$ = (CONT)			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ______

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ______

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ ______

ELEMENT DESCRIPTION OFFSHORE SURGE RELIEF SYSTEM.

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12244/01 Pressure Control Valve	5×10^{-10}	5×10^{-12}	15	.224	1.12×10^{-10}	1.12×10^{-12}
			$\sum F_i = 67$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.33×10^{-44}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 9.54×10^{-50}

NORMALIZED ELEMENT RELIABILITY RATING $\left|1-\left[(9)\div(8)\right]\right|$ .999

ELEMENT DESCRIPTION OFFSHORE DRAIN AND SLOPS HANDLING

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12331						
/01 LEVEL SWITCH	3.3×10^{-10}	10^{-12}	9	.529	1.76×10^{-10}	5.29×10^{-13}
/02 ALARM	10^{-12}	10^{-12}	8	.470	4.7×10^{-7}	4.70×10^{-13}
			$\sum F_i = 17$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 4.7×10^{-7}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 9.99×10^{-13}

NORMALIZED ELEMENT RELIABILITY RATING $\left|1-\left[(9) \div (8)\right]\right|$ .999

ELEMENT DESCRIPTION OFFSHORE EMERGENCY SHUTDOWN SYSTEM

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12342						
/01 VALVE ACTUATOR	10^{-8}	10^{-12}	10	.357	3.57×10^{-9}	3.57×10^{-13}
12343						
/01 PRESSURE SWITCH	10^{-10}	10^{-12}	9	.321	3.21×10^{-11}	3.21×10^{-13}
/02 ALARM	10^{-12}	10^{-12}	9	.321	3.21×10^{-13}	3.21×10^{-13}
			$\sum F_i$ = 28			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 3.60×10^{-9}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 9.99×10^{-13}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .99

ELEMENT DESCRIPTION OFFSHORE COMMUNICATIONS

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
12410 - Voice						
12411 - Wire						
12412 - RADIO						
12420 - DATA						
12421 - WIRE						
12422 - RADIO						
			$\sum F_i =$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ____________

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ____________

NORMALIZED ELEMENT RELIABILITY RATING $\left| 1 - \left[(9) \div (8) \right] \right|$ ____________

ELEMENT DESCRIPTION ONSHORE VALVES

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
13111, 13123, 13221						
/01 REMOTE INDICATOR	10^{-12}	10^{-12}	4	.071	7.1×10^{-14}	7.1×10^{-14}
/02 LOCAL INDICATOR	10^{-12}	10^{-12}	6	.107	1.07×10^{-13}	1.07×10^{-13}
13112, 13122, 13223, 13822.						
/01 PUSH BUTTON REMOTE	10^{-11}	10^{-12}	4	.071	7.1×10^{-13}	7.1×10^{-14}
/02 PUSH BUTTON LOCAL	10^{-11}	10^{-12}	4	.071	7.1×10^{-13}	7.1×10^{-14}
/03 MANUAL LOCAL	10^{-11}	10^{-12}	6	.107	1.07×10^{-12}	1.07×10^{-13}
/04 VALVE ACTUATOR	10^{-8}	10^{-12}	12	.214	2.14×10^{-9}	2.14×10^{-13}
/05 LIMIT SWITCHES	3×10^{-9}	10^{-12}	20	.357	1.07×10^{-9}	3.57×10^{-13}
			$\sum F_i = 56$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 3.21×10^{-9}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 5.71×10^{-13}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .999

ELEMENT DESCRIPTION ONSHORE BOOSTER PUMPS

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
13311						
/01 Pressure Indicator	10^{-12}	10^{-12}	18	.093	9.3×10^{-14}	9.3×10^{-14}
/02 PRESSURE TRANSMITTER	10^{-12}	10^{-12}	4	.021	2.1×10^{-14}	2.1×10^{-14}
/03 PRESSURE RECORDER	10^{-12}	10^{-12}	4	.021	2.1×10^{-14}	2.1×10^{-14}
/04 PRESSURE SWITCH	10^{-10}	10^{-12}	10	.052	5.2×10^{-12}	5.2×10^{-14}
/05 ALARM	10^{-12}	10^{-12}	18	.093	9.3×10^{-14}	9.3×10^{-14}
13312						
/01 TEMPERATURE INDICATOR	10^{-12}	10^{-12}	1	.005	5.0×10^{-15}	5.0×10^{-15}
13313						
/01 FLOW ELEMENT	10^{-12}	10^{-12}	14	.072	7.2×10^{-14}	7.2×10^{-14}
			$\sum F_i$ = (CONT)			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ______

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ______

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ ______

ELEMENT DESCRIPTION ONSHORE BOOSTER PUMPS (CONT)

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
13314						
/01 FLOW TRANSMITTER	10^{-12}	10^{-12}	12	.062	6.2×10^{-14}	6.2×10^{-14}
/02 FLOW CONTROLLER	10^{-12}	10^{-12}	12	.062	6.2×10^{-14}	6.2×10^{-14}
/03 PRESSURE CONTROLLER	10^{-12}	10^{-12}	12	.062	6.2×10^{-14}	6.2×10^{-14}
/04 SIGNAL SELECTOR	10^{-12}	10^{-12}	6	.031	3.1×10^{-14}	3.1×10^{-14}
/05 FLOW REGULATOR	10^{-12}	10^{-12}	12	.062	6.2×10^{-14}	6.2×10^{-14}
13315						
/01 LEVEL SWITCH	10^{-10}	10^{-12}	18	.093	9.3×10^{-12}	9.3×10^{-14}
/02 VIBRATION SWITCH	10^{-10}	10^{-12}	14	.072	7.2×10^{-12}	7.2×10^{-14}
/03 PRESSURE SWITCH	10^{-10}	10^{-12}	14	.072	7.2×10^{-12}	7.2×10^{-14}
/04 AIR ELIMINATOR	10^{-12}	10^{-12}	18	.093	9.3×10^{-14}	9.3×10^{-14}
/05 ALARM	10^{-12}	10^{-12}	7	.036	3.6×10^{-14}	3.6×10^{-14}
			$\sum F_i = 194$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.96×10^{-11}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 1.00×10^{-12}

NORMALIZED ELEMENT RELIABILITY RATING $\left| 1 - \left[(9) \div (8) \right] \right|$ .966

ELEMENT DESCRIPTION ONSHORE TANKS

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
13222						
/01 LEVEL TRANSMITTER	10^{-12}	10^{-12}	3	.130	1.3×10^{-13}	1.3×10^{-13}
/02 REMOTE INDICATOR	10^{-12}	10^{-12}	3	.130	1.3×10^{-13}	1.3×10^{-13}
/03 LOCAL INDICATOR	10^{-6}	10^{-12}	3	.130	1.30×10^{-7}	1.3×10^{-13}
/04 LEVEL SWITCHES	3.3×10^{-10}	10^{-12}	3	.130	4.3×10^{-11}	1.3×10^{-13}
/05 LEVEL ALARM	10^{-12}	10^{-12}	11	.478	4.78×10^{-13}	4.78×10^{-13}
			$\sum F_i = 23$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 5.68×10^{-18}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 1.13×10^{-25}

NORMALIZED ELEMENT RELIABILITY RATING $\left| 1 - \left[(9) \div (8) \right] \right|$ .999

ELEMENT DESCRIPTION ONSHORE SURGE RELIEF SYSTEM

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
13241						
/01 Valve ACTUATOR	10^{-8}	10^{-12}	24	.407	4.07×10^{-9}	4.07×10^{-13}
13242						
/01 Level SWITCH	10^{-12}	10^{-12}	6	.102	1.03×10^{-13}	1.03×10^{-13}
/02 High Level Alarm	10^{-12}	10^{-12}	6	.102	1.03×10^{-13}	$1.03 \times 10^{-}$
/03 Low Level ALARM	10^{-12}	10^{-12}	1	.017	1.7×10^{-14}	1.7×10^{-14}
13243						
/01 Pressure Indicator	10^{-12}	10^{-12}	1	.017	1.7×10^{-14}	1.7×10^{-14}
/02 Pressure Switch	10^{-12}	10^{-12}	7	.119	1.2×10^{-13}	1.2×10^{-13}
/03 ALARM	10^{-12}	10^{-12}	7	.119	1.2×10^{-13}	1.2×10^{-13}
			$\sum F_i$ = (CONT)			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ____________

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE ____________

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ ____________

ELEMENT DESCRIPTION ONSHORE SURGE RELIEF SYSTEM

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
13244/01 Pressure Control Valve	10^{-10}	10^{-12}	7	.119	1.2×10^{-11}	1.2×10^{-13}
			$\sum F_i = 59$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.73×10^{-45}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 2.73×10^{-51}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .999

ELEMENT DESCRIPTION ONSHORE PIPING

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
13323						
/01 PRESSURE INDICATOR	10^{-12}	10^{-12}	18	.409	4.09×10^{-13}	4.09×10^{-13}
/02 PRESSURE TRANSMITTER	10^{-12}	10^{-12}	4	.091	9.1×10^{-14}	9.1×10^{-14}
/03 Pressure RECORDER	10^{-12}	10^{-12}	4	.091	9.1×10^{-14}	9.1×10^{-14}
/04 ALARM	10^{-12}	10^{-12}	18	.409	4.09×10^{-13}	4.09×10^{-13}
			$\sum F_i = 44$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 1×10^{-12}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 1×10^{-12}

NORMALIZED ELEMENT RELIABILITY RATING $\left|1 - \left[(9) \div (8)\right]\right|$ 1.00 *

* 100% Relinble

ELEMENT DESCRIPTION ONSHORE DRAIN AND SLOPS HANDLING

EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
13331						
/01 LEVEL SWITCH	3.3×10^{-10}	10^{-12}	9	.530	1.7×10^{-10}	5.3×10^{-13}
/02 ALARM	10^{-12}	10^{-12}	8	.470	4.7×10^{-13}	4.7×10^{-13}
			$\sum F_i = 17$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 1.70×10^{-10}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 1.0×10^{-12}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .994

ELEMENT DESCRIPTION ONSHORE EMERGENCY SHUTDOWN SYSTEM

(1) EQUIPMENT IDENTIFICATION NUMBER	(2) EQUIPMENT PROBABILITY OF FAILURE	(3) BENCHMARK EQUIPMENT PROBABILITY OF FAILURE	(4) EFFECTS WEIGHTING FACTOR (F_i)	(5) EFFECTS WEIGHTING FACTOR FRACTION $\frac{F_i}{\sum F_i}$	(6) EFFECTS WEIGHTED PROBABILITY OF FAILURE (2)x(5)	(7) BENCHMARK EFFECTS WEIGHTED PROBABILITY OF FAILURE (3)x(5)
13342						
/01 VALVE ACTUATOR	10^{-8}	10^{-12}	10	.357	3.57×10^{-9}	3.57×10^{-13}
13343						
/01 PRESSURE SWITCH	10^{-10}	10^{-12}	9	.321	3.21×10^{-11}	3.21×10^{-13}
/02 ALARM	10^{-12}	10^{-12}	9	.321	3.21×10^{-13}	3.21×10^{-13}
			$\sum F_i = 28$			

(8) ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 3.60×10^{-9}

(9) BENCHMARK ELEMENT EFFECTS WEIGHTED PROBABILITY OF FAILURE 9.99×10^{-13}

NORMALIZED ELEMENT RELIABILITY RATING $\{1 - [(9) \div (8)]\}$ .999

APPENDIX D

EFFECTS RATING FACTOR WORKSHEET

TANKER EQUIPMENT		MAJOR SPILL	MEDIUM SPILL	MINOR SPILL	CATASTROPHIC HAZARD	CRITICAL HAZARD	MARGINAL HAZARD	NEGLIGIBLE HAZARD	LONG DELAY	SHORT DELAY	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
NUMBER	NAME	A	B	C	D	E	F	G	H	I	
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
	• <u>VALVES</u>										
11111	<u>Valve Line Up Monitor</u>										
11223	/01 Remote Indicator							1		3	4
	/02 Local Indicator							1	5		6
11112	<u>Valve Line Up Controller</u>										
11222	/01 Push Button Remote							1		3	4
	/02 Push Button Local							1		3	4
	/03 Manual Local							1	5		6
	/04 Valve Actuator						7		5		12
	/05 Limit Switches						7		5		12
	• <u>PUMPS</u>										
11211	<u>Pressure Monitor</u>										
11311	/01 Pressure Indicator			8			7			3	18
	/02 Pressure Transmitter							1		3	4
	/03 Pressure Recorder							1		3	4
	/04 Pressure Switch			8			7			3	18
	/05 Alarm			8			7			3	18

TANKER EQUIPMENT NUMBER	NAME	MAJOR SPILL A	MEDIUM SPILL B	MINOR SPILL C	CATASTROPHIC HAZARD D	CRITICAL HAZARD E	MARGINAL HAZARD F	NEGLIGIBLE HAZARD G	LONG DELAY H	SHORT DELAY I	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
11212	Flow Rate Controller										
11312	/01 Speed Indicator							1			1
11213	/02 Speed Regulator			8			7		5		20
11313	Pump Protection Devices										
	/01 Overspeed Trip					9			5		14
	/02 Temperature Switch					9			5		14
	/03 Low Lube Pressure Trip					9			5		14
	/04 Alarm					9			5		14
	• TANKS										
11221	Tank Level Monitor										
	/01 Level Indicator							1		3	4
	- Float Gage Read Switch										
	- Float Gage Tape										
	- Metri Tape										
	- Pneumatic										
	/02 Manual Dipping							1	5		6
	• PIPING										
11321	Pressure Monitor										
	/01 Pressure Indicator			8			7			3	18

TANKER EQUIPMENT		MAJOR SPILL	MEDIUM SPILL	MINOR SPILL	CATASTROPHIC HAZARD	CRITICAL HAZARD	MARGINAL HAZARD	NEGLIGIBLE HAZARD	LONG DELAY	SHORT DELAY	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
NUMBER	NAME	A	B	C	D	E	F	G	H	I	
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
11322	Hose/Loading Arm Drain										
	/01 Manual Procedure							1		3	4
	• EMERGENCY SHUTDOWN SYSTEM										
11330	/01 Midships Remote Pump Shutdown Switch	10				9			5		24
11330	/02 Control Room Remote Pump Shutdown Switch	10				9			5		24
	• COMMUNICATIONS										
11410	Voice										
	/01 SP Phone							1		3	4
11420	Radio										
	/01 VHF							1		3	4
	/02 Walkie-Talkie							1		3	4

OFFSHORE EQUIPMENT		MAJOR SPILL	MEDIUM SPILL	MINOR SPILL	CATASTROPHIC HAZARD	CRITICAL HAZARD	MARGINAL HAZARD	NEGLIGIBLE HAZARD	LONG DELAY	SHORT DELAY	F_i EQUIPMENT FAILURE EFFECTS
NUMBER	NAME	A	B	C	D	E	F	G	H	I	WEIGHTING FACTOR
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
	● VALVES										
12121	Valve Line Up Controller										
12322	/01 Push Button Remote							1		3	4
	/02 Push Button Local							1		3	4
	/03 Manual Local							1	5		6
	/04 Valve Actuator						7		5		12
	/05 Limit Switches			8			7		5		20
12122	Valve Line Up Monitor										
12321	/01 Remote Indicator							1		3	4
	/02 Local Indicator							1	5		6
	● BOOSTER PUMPS										
12231	Pressure Monitor										
12311	/01 Pressure Indicator			8			7			3	18
	/02 Pressure Transmitter							1		3	4
	/03 Pressure Recorder							1		3	4
	/04 Pressure Switch						7			3	10
	/05 Alarm			8			7			3	18
12232	Temperature Monitor										
12312	/01 Temperature Indicator							1			1

OFFSHORE EQUIPMENT		MAJOR SPILL	MEDIUM SPILL	MINOR SPILL	CATASTROPHIC HAZARD	CRITICAL HAZARD	MARGINAL HAZARD	NEGLIGIBLE HAZARD	LONG DELAY	SHORT DELAY	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
NUMBER	NAME	A	B	C	D	E	F	G	H	I	
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
12233	<u>Flow Monitor</u>										
12313	/01 Flow Element					9			5		14
12234	<u>Flow Rate Controller</u>										
12314	/01 Flow Transmitter						7		5		12
	/02 Flow Controller						7		5		12
	/03 Pressure Controller						7		5		12
	/04 Signal Selector							1	5		6
	/05 Flow Regulator						7		5		12
12235	<u>Pump Protection Devices</u>										
12315	/01 Level Switch			8			7			3	18
	/02 Vibration Switch					9			5		14
	/03 Differential Pressure Switch					9			5		14
	/04 Air Eliminator			8			7			3	18
	/05 Alarm						7				7
	• <u>PIPING</u>										
12111	<u>Oil In Hose/Loading Arm Detector</u>										
	/01 Pressure Indicator			8			7		5		20
12112	<u>Hose Loading Arm Drain</u>										
	/01 Manual Procedure							1	5		6
12211	<u>Pressure Monitor</u>										
12323	/01 Pressure Indicator			8			7			3	18

OFFSHORE EQUIPMENT		MAJOR SPILL	MEDIUM SPILL	MINOR SPILL	CATASTROPHIC HAZARD	CRITICAL HAZARD	MARGINAL HAZARD	NEGLIGIBLE HAZARD	LONG DELAY	SHORT DELAY	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
NUMBER	NAME	A	B	C	D	E	F	G	H	I	
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
	/02 Pressure Transmitter							1		3	4
	/03 Pressure Recorder							1		3	4
	/04 Alarm			8			7			3	18
12212	Temperature Monitor										
	/01 Temperature Indicator							1			1
12213	Flow Rate Monitor										
	/01 Measuring Device						7		5		12
	- Orifice Plate										
	- Sonic Meter										
12214	Flow Rate Controller										
	/01 Flow Indicator							1	5		6
	/02 Flow Controller						7		5		12
	/03 Flow Transmitter							1	5		6
	/04 Flow Regulator						7		5		12
	• SAMPLING										
12220	/01 Sampler							1			1
	• SURGE RELIEF SYSTEM										
12241	Surge Relief Availability Control										
	/01 Valve Actuator	10				9			5		24

OFFSHORE EQUIPMENT NUMBER	NAME	MAJOR SPILL A	MEDIUM SPILL B	MINOR SPILL C	CATASTROPHIC HAZARD D	CRITICAL HAZARD E	MARGINAL HAZARD F	NEGLIGIBLE HAZARD G	LONG DELAY H	SHORT DELAY I	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
12242	Surge Relief Availability Monitor										
	/01 Level Switch							1	5		6
	/02 High Level Alarm							1	5		6
	/03 Low Level Alarm							1			1
12243	Relief Valve Pressurization Medium Monitor										
	/01 Pressure Indicator							1			1
	/02 Pressure Switch						7				7
	/03 Alarm						7				7
12244	Relief Valve Pressurization Medium Controller										
	/01 Pressure Control Valves			8			7				15
	• DRAIN & SLOPS HANDLING										
12331	Drain Tank Level Monitor										
	/01 Level Switch		9								9
	/02 Alarm			8							8

OFFSHORE EQUIPMENT		MAJOR SPILL	MEDIUM SPILL	MINOR SPILL	CATASTROPHIC HAZARD	CRITICAL HAZARD	MARGINAL HAZARD	NEGLIGIBLE HAZARD	LONG DELAY	SHORT DELAY	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
NUMBER	NAME	A	B	C	D	E	F	G	H	I	
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
	• EMERGENCY SHUTDOWN SYSTEM										
12341	Valve Position Monitor										
	/01 Remote Indicators						7				7
12342	Valve Line Up Controller										
	/01 Valve Actuator	10									10
12343	Valve Actuating Medium Monitor										
	/01 Pressure Switch		9								9
	/02 Alarm		9								9
	• COMMUNICATIONS										
12410	Voice										
12411	- Wire										
12412	- Radio										
12420	Data										
12421	- Wire										
12422	- Radio										

ONSHORE EQUIPMENT		MAJOR SPILL	MEDIUM SPILL	MINOR SPILL	CATASTROPHIC HAZARD	CRITICAL HAZARD	MARGINAL HAZARD	NEGLIGIBLE HAZARD	LONG DELAY	SHORT DELAY	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
NUMBER	NAME	A	B	C	D	E	F	G	H	I	
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
	• VALVES										
13111 13123	Valve Line Up Monitor										
13221	/01 Remote Indicator							1		3	4
13321	/02 Local Indicator							1	5		6
13112 13122	Valve Line Up Controller										
13223	/01 Push Button Remote							1		3	4
13322	/02 Push Button Local							1		3	4
	/03 Manual Local							1	5		6
	/04 Valve Actuator						7		5		12
	/05 Limit Switches			8			7		5		20
	• BOOSTER PUMPS										
13211	Pressure Monitor										
13311	/01 Pressure Indicator			8			7			3	18
	/02 Pressure Transmitter							1		3	4
	/03 Pressure Recorder							1		3	4
	/04 Pressure Switch						7			3	10
	/05 Alarm			8			7			3	18
13212	Temperature Monitor										
13312	/01 Temperature Indicator							1			1
13213	Flow Monitor										
13313	/01 Flow Element					9			5		14

ONSHORE EQUIPMENT		MAJOR SPILL	MEDIUM SPILL	MINOR SPILL	CATASTROPHIC HAZARD	CRITICAL HAZARD	MARGINAL HAZARD	NEGLIGIBLE HAZARD	LONG DELAY	SHORT DELAY	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
NUMBER	NAME	A	B	C	D	E	F	G	H	I	
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
13214	<u>Flow Rate Controller</u>										
13314	/01 Flow Transmitter							1	5		6
	/02 Flow Controller						7		5		12
	/03 Pressure Controller						7		5		12
	/04 Signal Selector							1	5		6
	/05 Flow Regulator						7		5		12
13215	<u>Pump Protection Devices</u>										
13315	/01 Level Switches			8			7			3	18
	/02 Vibration Switch					9			5		14
	/03 Differential Pressure Switch					9			5		14
	/04 Air Eliminator			8			7			3	18
	/05 Alarm						7				7
	• <u>TANKS</u>										
13222	<u>Tank Level Monitor</u>										
	/01 Level Transmitter									3	3
	/02 Remote Indicator									3	3
	/03 Local Indicator									3	3
	/04 Level Switches									3	3
	/05 Level Alarm			8						3	11
	• <u>SURGE RELIEF SYSTEM</u>										
13241	<u>Surge Relief Availability Control</u>										
	/01 Valve Actuator	10				9			5		24

ONSHORE EQUIPMENT		MAJOR SPILL	MEDIUM SPILL	MINOR SPILL	CATASTROPHIC HAZARD	CRITICAL HAZARD	MARGINAL HAZARD	NEGLIGIBLE HAZARD	LONG DELAY	SHORT DELAY	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
NUMBER	NAME	A	B	C	D	E	F	G	H	I	
	EFFECTS WEIGHTING ←	10	9	8	10	9	7	1	5	3	SUMMATION
13242	Surge Relief Availability Monitor										
	/01 Level Switch							1	5		6
	/02 High Level Alarm							1	5		6
	/03 Low Level Alarm								1		1
13243	Relief Valve Pressurization Medium Monitor										
	/01 Pressure Indicator							1			1
	/02 Pressure Switch						7				7
	/03 Alarm						7				7
13244	Relief Valve Pressurization Medium Controller										
	/01 Pressure Control Valves						7				7
	• PIPING										
13323	Pressure Monitor										
	/01 Pressure Indicator			8			7			3	18
	/02 Pressure Transmitter							1		3	4
	/03 Pressure Recorder							1		3	4
	/04 Alarm			8			7			3	18

ONSHORE EQUIPMENT		MAJOR SPILL	MEDIUM SPILL	MINOR SPILL	CATASTROPHIC HAZARD	CRITICAL HAZARD	MARGINAL HAZARD	NEGLIGIBLE HAZARD	LONG DELAY	SHORT DELAY	F_i EQUIPMENT FAILURE EFFECTS WEIGHTING FACTOR
NUMBER	NAME	A	B	C	D	E	F	G	H	I	
	EFFECTS WEIGHTING	10	9	8	10	9	7	1	5	3	SUMMATION
	● DRAIN & SLOPS HANDLING										
13331	Drain Tank Level Monitor										
	/01 Level Switch		9								9
	/02 Alarm			8							8
	● EMERGENCY SHUTDOWN SYSTEM										
13341	Valve Position Monitor										
	/01 Remote Indicator						7				7
13342	Valve Line Up Controller										
	/01 Valve Actuator	10									10
13343	Valve Actuating Medium Monitor										
	/01 Pressure Switch		9								9
	/02 Alarm		9								9

APPENDIX E

EQUIPMENT DESCRIPTION

APPENDIX E
EQUIPMENT DESCRIPTION

E-1 INTRODUCTION

Generally speaking, the term "Control System" implies the means required to operate automatically an assemblage of devices and equipment that will perform some desirable function and produce some desired result with a minimum of human intervention.

The control-mode, that is, the type of control action which the controller takes in directing the final controlling device, may vary from simple on-off action to the more complex proportional - plus - integral action. Table E-1 shows the various control modes as applied in general process control and as applied specifically to Deepwater Ports.

The interaction of control systems within a DWP must be carefully considered. For instance, an automatic flow control system on a platform complex would interact with the tanker pump controls. If the pump controls include pressure or flow control loops, then the platform flow control will act as a master controller, effectively changing the rate of pumping; however, time lags through long submarine pipelines may make this type of control undesirable. On the other hand, if the pump relies on manual adjustment to change the rate of flow, then the flow controller could control the pumps on an on-off basis through its protective devices, which is, again, undesirable. It can be assumed that if the type of pump control on board tankers cannot be determined, then the interaction with the flow control on the platform complex should be studied. Flow control, which is an integral part of the controls of a booster pumping station, would not directly interact with the ship's pumps.

CONTROL MODE	REACTION TIME	GENERAL APPLICATION	DWP APPLICATION
On-Off	Slow	Large capacity temperature and level installations. Storage tanks, hot water supply tanks.	Tanker storage tanks, onshore storage tanks, drain/slop tanks surge tanks, booster pump protection devices.
Proportional (P)	Slow to Moderate	Pressure, temperature, level where offset[1] can be tolerated. Kettle reboiler level, drying oven temperature, pressure reducing stations.	Not normally used.
Proportional-plus-derivative (rate[2]) (P+D)	Moderate	Where increased stability with minimum offset and of reset[3] wind-up is required. Compressor discharge pressure.	Booster pumps controls which measure pressure.
Proportional-plus-integral (reset[3]) (P+I)	Adjustable	Most applications including flow.	Main flow control. Metering flow control. Booster pumps controls which measure pressure.
Proportional-plus-integral-plus-derivative (P+I+D)	Adjustable	Batch control; processes with sudden upsets.	Not applicable

1. Offset: The deviation between actual value and the desired value or set point of a controlled variable that exists as a characteristic of proportional control. The degree of offset is proportional to the load conditions.

2. Rate: Where the output of the controller is proportional to the rate of change of the input.

3. Reset: Where the rate of change of the output of the controller is proportional to the input.

TABLE E-1. CONTROL MODES VS. APPLICATION

E-1.1 VARIABLES

The process variables to be measured and controlled on a Deepwater Port complex are:

- Pressure
- Flow
- Level
- Temperature

These variables and the basic methods employed in their measurement and control are the subject of the following discussions.

PRESSURE

Pressure is the most commonly measured variable on a DWP oil transfer system. Gauges are located on the pipelines wherever it is considered an assistance to the operators, i.e., pump suction and discharge piping, the piping at the base of loading arms, sections of piping which can be subject to thermally induced pressure increases, adjacent to pressure switches and transmitters, adjacent to pressure regulators, and monitoring auxiliary compressed gas supplies.

Pressure indication, whether it be by gauges on the pipeline or by remote indicator or alarm, tells the operating personnel what is going on inside the piping systems. Examples of this are:

- The operation of remote pumping systems

- Whether control systems, such as flow and pressure regulators, are working correctly

- Whether other instruments, such as pressure transmitters and switches, are working correctly

- The level of oil in loading arm risers

- The correct setting of thermal and other relief systems

The most common method of determining the system pressure is by Pressure Gauge or Indicator mounted on the pipeline. Remote pressure indication employs a transmitter which is also connected directly to the pipeline and functions similarly to the gauge. Pressure switches, which initiate remote alarms, are also mounted and function similarly to the gauge. Section E-1.2 describes the principles and operation of these instruments.

FLOW

The measurement and control of flow rates through a DWP are necessary, not only for determining quantities, but also because of the design limitations of other equipment and facilities built into the oil transfer system. The velocities through hoses and loading arms are restricted, due in part to the vibration at excessive flow rates. The filling rates of fixed or floating roof tanks are restricted by the physical rate of tank venting or roof travel. The accuracy of flow metering is reduced if flow rates move outside recommended ranges.

Flow rate measurements are readily converted into totalized quantities and can, therefore, be used as accurate measurements for custory transfer or leak detection by differential flow measurement.

Various well proven methods of flow measurement are available although some, such as variable-area, electromagnetic and vortex meters, or open weirs and flumes, are not suitable for the high throughputs and large pipeline sizes of a DWP.

Table E-2 shows the various types, ranges and applications of those methods employed on DWPs. A more detailed discussion on metering appears later in this Appendix.

LEVEL

Essentially, the moving of crude oil through a Deepwater Port facility is the transfer of oil from one storage to another. Level measurements, therefore, become very important on the discharging tanker and at the onshore tank farm.

A variety of methods for continuous level measurement are in use today which range from the simple float and tape to a system employing nuclear radiation. Each has its own advantages and limitations. Table E-3 presents these together with ranges and accuracies.

The systems commonly used on oil tankers are the float and tape, gas bubbler, capacitance and resistance types. Normally, at least two level systems of different types are installed to provide redundancy for safety.

The float and tape system is the most commonly used method in the onshore storage tanks. This method has the advantage of good accuracy and proven performance over a number of years.

For point detection of liquid levels, the mechanical float

TYPE	RANGE (FOR DWP SIZES)	ACCURACY	LIMITATIONS	GENERAL APPLICATION	DWP APPLICATION
Volumetric Meters (Lobed rotor)	2,500 BPH to 12,500 BPH	$\pm$ 0.20%	Large & bulky. Inaccurate at low flows. Not available above 16".	Batching & blending stations. Custody transfer measurement.	Used extensively on early DWPs displaced by turbine meters in last decade.
Velocity Meters (Turbines)	8,000 BPH to 60,000 BPH	+ 0.15%	Relatively high cost. Limited range of viscous liquids can be handled.	Batching & blending stations. Custody transfer measurement.	Custody transfer and leak detection.
Variable Head Meter Orifice Plate	Up to 72" pipe	$\pm$ 0.5%	Permanent pressure loss. Straightening vanes or straight lengths of pipe required upstream.	Flow measurement for remote indication and recording. Primary element for flow control loop.	Remote indication and primary element for automatic control system, particularly where no metering facilities are installed.
Variable Head Meter Dall Tube	No upper limit	$\pm$ 0.5%	Permanent pressure loss. Straightening vanes or straight lengths of pipe required upstream. More costly than orifice plate.	Flow measurement for remote indication and recording. Primary element for flow control loop.	Remote indication and primary element for automatic control system, particularly where no metering facilities are installed.
Sonic Meter	No upper limit	Unknown at high throughputs	Output varies with specific gravity of liquid. Unproven in large sizes. Probes subject to erosion.	Process units with relatively small flows and single specific gravity. Blending stations.	Remote indication and recording.

TABLE E-2. PRIMARY ELEMENTS FOR FLOW MEASUREMENT

TYPE	RANGE	ACCURACY	LIMITATIONS	GENERAL APPLICATION	DWP APPLICATION
Float & Tape	0-75 Ft.	± 1/16"	Float subject to accumulation of sludge in crude oil service.	Uniform storage tanks. Local and remote indicator.	Ships' tanks, remote indication. Onshore tanks, remote indication.
Float & Arm	6"-10 Ft.	± 2% span	Float subject to accumulation of sludge in crude oil service.	Indication and alarm levels in all types of tanks.	Onshore storage tanks.
Gas Bubbler	Gauge sensitivity to tank height	± 1% span	Requires density connection. Tank must be vented.	Ships' tanks, remote indication.	Ships' tanks, remote indication.
Continuous Radiation	1"-20 Ft.	+1-3% span	Requires density connection. Relatively	Molten metals, corrosive liquids, high temperature/pressure applications.	Not used.
Capacitance	3" to Tank Height	± 0.5% span	Output affect by changes in resistence content of measured fluid.	Most applications. Aircraft fuel tanks.	Ships' tanks, remote indication.
Resistence (Pressure sensitive sheath)	2 to 200 Ft.	± 1"	Relatively poor accuracy.	Ships' tanks. All liquid or granular solid storage tanks.	Ships' tanks, remote indication.

TABLE E-3. LEVEL MEASURING SYSTEMS

arm level switch is installed which is readily adaptable to external mounting on the shells of floating roof tanks.

TEMPERATURE

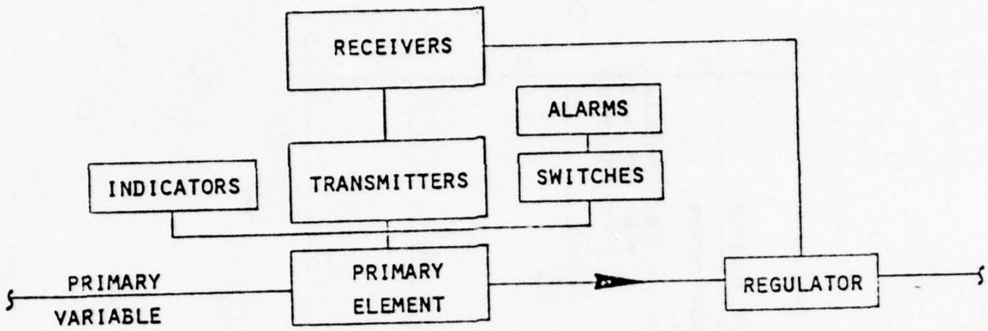
Temperature measurements of the crude oil in a DWP are relatively unimportant unless quantity measurements for custody transfer or leak detection take place.

Metering stations measuring precise quantities have to take into account thermal changes and apply temperature correction factors to the measured volumes. This is done by means of automatic temperature compensating devices employing a resistance type temperature measuring probe.

Where temperature corrections are applied to onshore storage tank quantities, average temperature must be measured. Usually, a series of thermocouples are used which are connected to give an average reading. These can be installed around the tank perifery or, for tanks with floating roofs, it is more common to install a vertical bundle of thermocouples which pass through the roof and which average the temperatures at various levels.

E-1.2 CONTROL SYSTEMS COMPONENTS

The following is a general description of the component parts which make up control systems as shown in the following diagram. Only those components found on Deepwater Ports have been considered.



CONTROL SYSTEM COMPONENTS

PRIMARY ELEMENT

This is a device that detects or senses the value or change of value of the variable being measured; in other words, it is the first link in the measurement - control system chain.

The following are primary elements grouped by process variable:

- Pressure Measurement:

  The primary elements for pressure measurement include the Bourdon Tube, Bellows or Diaphragm, all of which translate pressure into physical movement and can be used in any pressure measuring instrument whether it be a pressure gauge, transmitter or switch. Refer to Table E-4 for comparison.

  The principle of operation is the elastic properties of the element which changes shape as pressure is applied internally. The resulting movement is amplified through linkage and gears to an indicating pointer or signal-producing

TYPE	RANGE (PSIG)	GENERAL APPLICATION	DWP APPLICATION
Bourdon Tube ("C" Type Helical Spiral)	0-100,000	Pressure Gauges, recorders and transmitters	All pressure instruments. Typical ranges: Oil transfer system - 0- 300 psig Loading Arms - 0- 15 psig Compressed Gas - 0-2000 psig
Bellows	0-100	Special applications where Bourdon Tubes would be impracticable. Pressure receiving instruments.	Not used.
Metallic Diaphragm	0-200	Aircraft instruments	Not used.

TABLE E-4. PRESSURE ELEMENTS

device. The material used in the manufacture of these elements is varied. The most commonly used material on DWPs is 316 stainless steel which has good corrosion resisting properties in a marine environment.

- Flow Measurement:

1. Orifice Plate

An Orifice Plate is a circular plate with a round hole in the center which is clamped in the pipeline between flanges. These flanges are drilled and tapped so that the pressure on each side of the plate can be sensed by a differential pressure measuring instrument. During flow conditions, the restriction of the orifice causes a pressure loss. This loss, measured as the difference between the upstream and downstream pressures, is proportional to the square root of the flow rate.

2. Positive Displacement (PD) Meter Rotor

This method of accurate flow quantity measurement employs the principle of a rotating mechanism having cavities of known volume. The flowing liquid rotates the meter which moves known volumes in the cavities from one side to the other. Each rotation transfers a measured quantity of liquid, therefore, the number of revolutions is a positive indication of the volume passed.

3. Turbine Meter Impeller

Just as accurate as the PD Meter, the Turbine

Meter requires less space and can handle greater flow rates. The impeller mounted inside a short length of machined pipe is free to rotate on bearings. The flowing liquid impinging on the impeller blades causes it to turn. A steady rotational speed is proportional to the liquid velocity - hence, the volume flow rate.

4. Dall Tube

This device employs the same principle of differential pressure measurement across a restriction in the pipeline as the Orifice Plate. The Dall Tube is much longer than the Orifice Plate but causes less permanent pressure loss.

5. Sonic Meters

Two probes are required in this type of flow measurement which uses the principle of variation in the speed of sound in a liquid which is proportional to variations in the velocity of that liquid. This is a recently developed technique which has the limitation of being affected by density changes in the flowing liquid.

The two probes, mounted diametrically opposite one another in the pipeline, are subject to erosion from solids in suspension.

- Level Measurement:

1. Float and Tape

Liquid level in high-rise tanks, including ship's

tanks can be measured to better than ±1/8" with a float and tape arrangement. The float, usually made from a material such as 316 stainless steel, which is impervious to crude oils and a marine environment, travels inside a "still well" or perforated vertical pipe which protects the float from any disturbances in the tank. It is important that the specific gravity of the float is not changed by the accumulation of debris or sludge; this will have an adverse affect on the accuracy of level readings.

2. Float and Arm

The application of this type of level measuring element is generally confined to point indication of liquid levels for alarm initiation. Several principles of design are available, all of which achieve the basic requirement of transmitting the float movement to a switching device through some sort of sealing barrier. The most common types are those which employ the following methods: tube/rod arms, magnet and follower and bellows.

a. The tube/rod arrangement has a rod inside a tube, both of which are fixed to the float. The tube with the rod inside it passes through a sealing bulkhead to which it is welded. The tube is "pinched" on the float side of the bulkhead to provide a pivot point. The float/arm assembly moves up and down about the pivot; simultaneously, the internal rod moves a corresponding amount on the other side of the bulkhead. This movement actuates a switch mechanism.

b. The magnet/follower principle is simply a magnet fixed to the float arm which actuates a follower on the other side of the sealing barrier.

c. The bellows arrangement allows the arm to pass through the end of the bellows which, apart from providing a sealing barrier, also gives the flexibility necessary to transmit the float movement to a switch mechanism.

3. Capacitance

The principle of changes in a tank level varying the electrical capacitance of a probe is used in the design of these instruments. For conductive fluids, such as crude oil, an insulated vertical probe is used wherein the capacitance of the insulated sensor varies with the level. Electrical span and zero adjustment in the electric circuitry make it conveniently possible for capacitance systems to be adjusted for accurate, continuous measurement of liquid level.

Capacitance probes are also used as point sensing alarm elements.

4. Gas Bubbler

The pressure necessary to overcome the head of liquid in a tank is a measure of the level in that tank. Compressed air is pumped into the bottom of a tank and a pressure gauge mounted on the same air supply piping indicates the pressure

required to "bubble" air into the liquid. The scale of the gauge is calibrated in units of liquid level. Since crude oils vary in specific gravity, a system of specific gravity compensation has been devised. Two air pressure connections in the side of the tank are installed with a known vertical distance between them. The difference in the pressures required to bubble air through both connections is related to specific gravity of the liquid in the tank. In other words, if the tank contained fresh water at 60°F and the connections were placed 2.31 feet apart, then the difference in pressure would be 1 psi. If the specific gravity of the water was increased, then the difference in pressure would also increase proportionally.

5. Resistance

This simple method uses a resistance strip inside a pressure-sensitive sleeving. Variations in level will short out the resistance strip at varying lengths. A simple potentiometer type circuit measures the changing resistance and relates it to level measurement.

- Temperature Measurement:

1. Thermal Bulb

The principle is that which is used in the clinical thermometer where a temperature sensitive liquid expands within a confined tube or capillary. The industrial thermometer uses stainless steel bulbs and tubes normally filled with mercury. The

expansion of the mercury causes movement in an elastic element similar to the pressure measuring elements. This movement drives a pointer or actuates a switch or compensating mechanisms.

2. Resistance Wire

The characteristic relationship of electrical resistance to temperature in pure metals is utilized in this primary element. A simple resistance measuring circuit determines the resistance of a wire element which is subject to temperature variations and translates them into temperature measurements.

3. Thermocouple

A temperature measuring device based on the phenomenon that an electric current flows in a continuous circuit formed by wires of dissimilar metals if the junctions between the two wires are at different temperatures. The resulting EMF produced in the thermocouple circuit is measured and used for indication, compensation or control of the actual temperature.

INDICATORS

These instruments are mounted close to the measuring point of the variable to be measured. Most indicators incorporate a primary element as described in the foregoing section.

Generally, the local indicators used on a DWP are the simple fixed dial with a moving pointer.

The following list groups indicators by process variable:

- Pressure Indicators

  The well-known pressure gauge which employs a pointer driven around a circular seal by a primary element (usually a "C" type Bourdon tube).

- Flow Indicators

  Although not normally used on oil transfer systems, they are sometimes found on tank drainage systems to indicate flow or no flow conditions in a pipeline.

  The principle used is simply a disc or target on a suitable arm, which is mounted in the direct line of flow. The velocity of the liquid moves the target which causes an indicator flag to appear on the outside of the pipe.

- Level Indicator

  The most common is a vertical linear scale and pointer system installed on the outside of a tank. The pointer is driven up and down the scale by a float inside the tank, a cable or tape attaches the pointer to the float via a series of pulleys.

- Temperature Indicator

  A thermometer, usually of the mercury-in-steel type with a circular dial and pointer driven by expansion within the primary element.

TRANSMITTERS

Transmitters take the output of the primary element, transform it into a transmittable form and transmit the resulting signal to remote receiving instruments.

- **Pressure Transmitter**

  The principle of operation is to take the movement produced by the primary element and apply it to a series of bellows and nozzles which produce a pneumatic signal relative to the measured pressure. For an electrical transmitter, the movement is used to vary the position of a mechanism producing a milliamp signal which is directly related to the measured pressure.

- **Flow Transmitter**

  1. Variable Head Meters (Orifice Plate and Dall Tube)

     The flow transmitter accepts the two pressures produced by the variable head type of flow primary device. These low and high pressures are applied to either side of a sealed capsule which is fixed to a force balance beam. The resulting movement of the beam is translated into a pneumatic or electrical signal in a similar fashion to that found in the pressure transmitter.

  2. Rotating Flow Meters (PD Meter and Turbine Meter)

     The rotation of the meter internals produces a pulse signal either directly or by means of gearing. PD meters employ a system whereby a slotted disc

is rotated and cuts the light source of a photo-electric circuit. Turbine meters use a magnetic impulse generated by the tips of the turbine blades passing a magnetic source.

The pulse signal in both cases is transmitted to remote receiving instruments.

- <u>Level Transmitters</u>

1. <u>Float and Tape</u>

   As the float follows the varying liquid level in the tank, a drum, driven by a tension spring or electric drive takes up the slack and stores the tape. The revolutions of this drum are directly related to the position of the float and, hence, the liquid level in the tank. It is the rotational position of the drum which is electrically transmitted to the remote receiving instruments.

2. <u>Capacitance and Resistance</u>

   Both these methods of level measurement transmit the varying capacitance or resistance, without transforming it, to the remote receiving instruments over a simple wire circuit.

3. <u>Gas Bubbler</u>

   The pneumatic back pressure which is the output of the primary device may be transmitted without change to remote receiving instruments, or it may use a pressure transmitter as described earlier.

- Temperature Transmitters

  1. Resistance Wire

     The transmission of varying resistance output of the primary device requires no transmitter to transform it to a communicable signal. The receiving instrument measures the resistance output as one leg of a bridge circuit.

  2. Thermocouple

     The transmitting wires of a thermocouple circuit are known as compensating leads. The semi-rare metals used for the thermocouple itself would be too costly to use as transmission wires. It is the usual practice to use compensating leads of a less expensive material which has characteristics close to the metals used for the thermocouple. No transmitter is involved since the receiving instrument measures directly the EMF produced by the thermocouple.

SWITCHES

For the variables being considered, the switches which initiate remote indicators and alarms operate on the same principles as transmitters. The movement of the primary elements operates switch mechanisms instead of transmitting mechanisms.

ALARMS

Basically, "alarms" are receivers similar to other indicators, their function is to provide protection by maintaining critical points in a system under constant surveillance. In a

complex such as a DWP, where centralized control is common, the alarms would be grouped together into an annunciator mounted on a control panel. An annunciator displays a series of engraved translucent windows which become back-illuminated in the event of an alarm. Upon actuation of an alarm point, the alarm light will flash, illuminating the appropriate window, and the horn or audio device sounds. A means for silencing the alarm and switching the light to a steady "on" state is provided; a reset switch will extinguish the light only when the alarm condition has been rectified.

Because these devices must remain operable over long periods of inactivity, test circuits are built into the annunciator so that periodic testing of the system can be carried out.

RECEIVERS

The remote instruments which "receive" the signals from the transmitters fall into three basic categories:

Indicators
Recorders
Controllers

These instruments are usually mounted on the control panel in the central control station.

- Indicators
  1. The conventional type of scale and pointer type of indicator is the most common. Two variations are available, those with a fixed scale and moving pointer, or those with a fixed pointer and moving scale. Which are used is immaterial and depends upon the designers choice.

2. Digital indicators lend themselves well to the remote indication of liquid levels and can be adopted for all other variables.

- <u>Recorders</u>

  Essentially, recorders are indicators which produce a permanent record. These receivers are generally panel mounted in control rooms and produce records on small strip charts. Certain variables which can be transformed to a digital form may be concentrated at a central recording station where they are recorded in digital form.

- <u>Controllers</u>

  These panel-mounted receiving instruments are the master link in a closed loop control system. Sometimes mounted integrally with records or indicators, the controller accepts the signal from the transmitter, considers it with respect to its own set point and mode of control and sends a controlling signal to the regulating device. The introduction to this Appendix explains the various control modes employed.

ACTUATORS

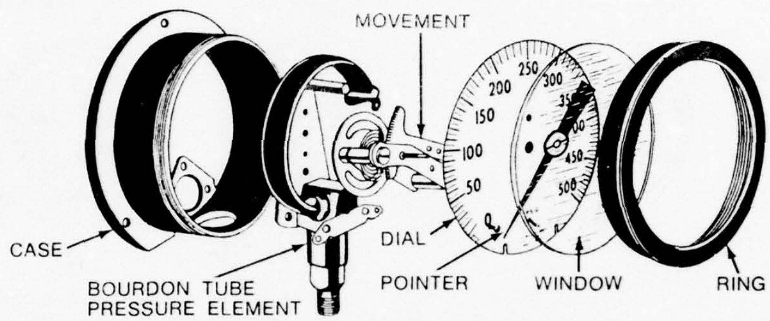
The actuators in this study are the devices which receive the controlling signal from a remote controller or from a command initiated by operating personnel, either locally or remotely. The actuator interprets the signal and "actuates" the regulating device, usually a valve.

On a Deepwater Port oil transfer system, the majority of

the valves, or regulators, are actuated electrically and are usually either fully open or fully closed.

Where more precise control is required between the two limits of open or closed, such as flow or pressure control at booster pumping station, the actuator uses a combination of electric and hydraulic or electric and pneumatic systems. In these cases, the electrics are the initiating and signalling devices and the hydraulics or penumatics are the driving force which actually moves the valve.

Most actuators, whether they be electric, electro/hydraulic or electro/pneumatic are fitted with a series of switches which initiate remote indication of the valve position and provide the switching necessary for interlocking systems such as that found on complex manifolds.



WARNING: All gauge components should be selected considering media, and ambient operating conditions, to prevent mis-application. Improper application can be detrimental to the gauge, cause failure and possibly personal injury or property damage.

The information contained in this catalog is offered as a guide to assist in making the proper selection of a pressure gauge.

Additional information is available from Dresser Industrial Valve and Instrument Division.

Pressure ranges — Select a gauge with a full scale pressure range of approximately twice the normal operating pressure. The maximum operating pressure should not exceed approximately 75% of the full scale range. Failure to select a gauge range within these criteria may ultimately result in fatigue failure of the Bourdon tube or bellows.

Operating conditions — The operating conditions to which a gauge will be subjected must be considered. Other than discoloration of the dial and hardening of the gaskets that will occur as ambient temperatures exceed 150 F., metal and phenol case gauges, that are not liquid filled, can withstand continuous ambient temperatures as high as 350 F. Gauges with soft soldered joints, however, should not be subjected to temperatures above 150 F. Accuracy will be affected by approximately 1.5% per hundred degrees F. Gauges with welded Bourdon tube (system) joints will withstand 750 F, with silver brazed joints, 450 F, for short times without rupture although other parts of the gauge will be destroyed and calibration will be lost. If the gauge will be subjected to severe vibration or pressure pulsation, the use of a liquid filled gauge is recommended.

Cases — Five case styles and four different materials are offered — aluminum, stainless steel, cast iron and phenol. All cases are open front, with the dial between the Bourdon tube and the window. An optional blowout disc can be supplied which will relieve case pressure buildup in the event a slow leak develops in the pressure element.

Pressure elements — Available for a wide variety of media: materials include: brass, phosphor bronze, alloy steel, AISI 316 stainless steel and K-monel. Proper selection of the Bourdon system or bellows material is dependent on the process fluid to which the system will be subjected. If the correct material is not available, the use of a diaphragm seal may be necessary to protect the system from the process fluid.

Movements — Movement parts are designed and protected to reduce friction and extend wear life. Each movement is ultrasonically cleaned and lubricated. Movements of 2 1/2" and 3 1/2" gauges, including bellows type, are stainless steel with Teflon* coated pinion gear and segment shaft; on 4 1/2" and larger sizes, gauges have stainless steel movement with bronze pinion and segment shaft.

Dials — Dials are uniformly graduated and have highly legible black markings. White or brushed aluminum backgrounds provide a high degree of resolution.

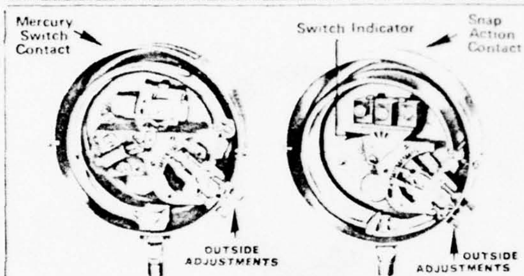
Pointers — Adjustable pointers are standard on Type 1009 gauges. Other gauges are supplied with non-adjustable pointers which can be reset by removing the ring, removing and resetting the pointer. Adjustable pointers are available as an option on these gauges.

Windows — The standard is glass: Non glare glass is optional for applications requiring that reflection be eliminated. Acrylic plastic or shatterproof glass windows are also available, to provide added resistance to breakage.

Rings — The rings, which enclose the window, are of several different types: friction, threaded, bayonet (cam), hinged, or snap design depending upon case.

2 SELECT YOUR OPERATING REQUIREMENT

ADJUSTABLE DIFFERENTIAL
FULLY AUTOMATIC – DOUBLE ADJUSTMENTS



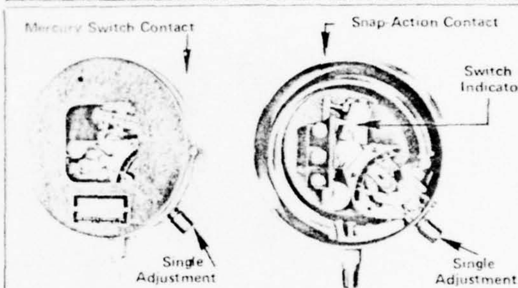
TYPES DA, DAF, DAH, DAHF, DAW, N3-DAW

Equipped with two outside adjustments - one for setting "high" pressure operating point and one for setting "low" pressure set point. Differential (difference between the "high" and "low" set points) is adjustable over the full scale.

Controls with mercury switch contacts are available SP-ST or in a variety of multiple circuits.

Controls with snap-action contacts have a switch indicator for visible operation and are available SP-DT or DP-DT. (2 SP-DT switches).

FIXED DIFFERENTIAL
FULLY AUTOMATIC – SINGLE ADJUSTMENT



TYPES DS, DSF, DSH, DSHF, DSW, N3-DSW

Equipped with a single adjustment for setting operating point only. A single pointer on the scale sets the pressure point where switch operation occurs. Fixed differential is factory set and cannot be changed.

Controls with mercury switch contacts have visible on/off operation and are available SP-ST only.

Controls with snap-action contacts have switch indicator for visible on/off operation and are available SP-DT only.

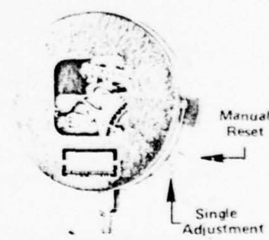
SEMI-AUTOMATIC WITH MANUAL RESET
SINGLE ADJUSTMENT

TYPES DR, DRF, DRH, DRHF, DRW, N3-DRW

A single adjustment sets the operating point to either "OPEN" or "CLOSE" the circuit automatically upon a pressure decrease or increase. A push button reset must be operated manually to restore the circuit to the original position after automatic operation.

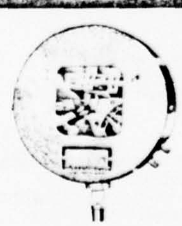
Suffix –L after Type No. denotes control will operate automatically on an increase.

Suffix –U after Type No. denotes control will operate automatically on a decrease.



3 SELECT YOUR ENCLOSURE

INDOOR



GENERAL PURPOSE
NEMA 1

TYPES DA, DR, DS *For applications where* atmospheric conditions are normal. For protection against dust and light splashing. Heavy gauge plain case (steel) with glass fronted cover. Finish charcoal gray. ¼" NPT pressure connection. Electrical connection back of case for ½" Conduit or BX. Locking device to prevent tampering with adjustments. Available with flanged case.

Dimensions Page 65

OUTDOOR

WATERTIGHT – DUSTTIGHT
NEMA 3S and 4

TYPES DAW, DRW, DSW: Meets hose test, also requirement for dusttight, driptight, weather-resistant, weather proof, splash proof, sleet proof, moisture resistant, watertight. Standard with flanged case, bottom connection (surface mounting only). Pressure connection ¼" NPT. Case and cover heavy gauge steel with UL listed metallic acrylic enamel finish. Glass fronted cover. External adjustments protected by bolted cover. ½" Conduit opening back of case with ½" removable hub.

WEATHER RESISTANT (RAINTIGHT)
NEMA 3R

TYPES N3-DAW, N3-DRW, N3-DSW. Similar to Watertight except includes drain in cover and does not have removable ½" hub.

Dimensions Page 65

HAZARDOUS LOCATIONS

EXPLOSION-PROOF

Class I Group C & D, NEMA 7. Class II, Group E, F, G. Class III, NEMA 9, 9A. Division 1

TYPES DAH, DRH, DSH: The control mechanism is an integral part of the case and cannot be removed in the field. For surface, panel or pipe mounting. Pressure connection ½" male thread with ¼" female thread. External adjustments. Shatter proof glass fronted cover. Finish natural aluminum. Available with breather and drain.

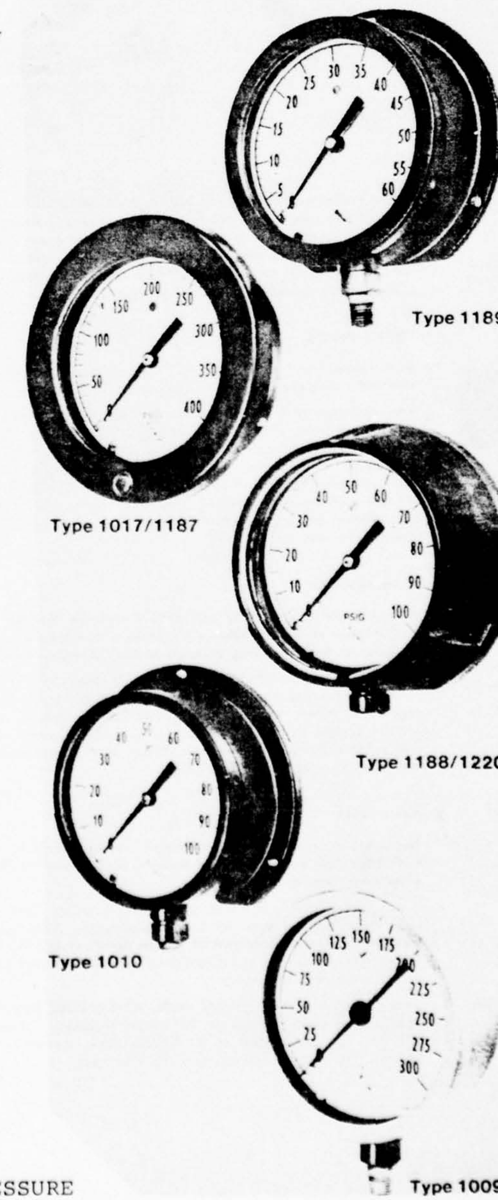
Dimensions Page 65

Several important variables must be considered when selecting the type of case for the application. A gauge is subject to environmental and atmospheric conditions, and the gauge internals must be protected from these elements.

Type of mounting — stem, surface or flush is important, as is the pressure connection location, lower or back. General characteristics of case styles are described below.

The following cases are all open front design, with the dial between the pressure system and the window. For maximum safety, an Ashcroft Duragauge* solid front gauge should be specified (a solid wall is between the pressure system and window). Request Bulletin DU-1.

Comprehensive reference charts of case styles, materials, and physical characteristics of General Service Gauges are on pages 10 and 12; dimensional drawings are on pages 14-18.



Type 1189

Type 1017/1187

Type 1188/1220

Type 1010

Type 1009

Type 1009

Polished stainless steel case and bayonet lock ring in 2$^1/_2$", 3$^1/_2$", and 4$^1/_2$" sizes. Maximum corrosion resistance. Available for stem, surface, or flush mounting, lower and back connected.

Type 1188/1220

Black, phenol turret cases in 4$^1/_2$", 6", 8$^1/_2$" sizes, with stainless steel snap ring. Lightweight, offers high resistance to corrosion. Stem or surface mounted; can be flush panel mounted with an accessory ring.

Type 1189

Aluminum case with threaded aluminum ring. Case and ring are black epoxy coated. 4$^1/_2$" and 6" sizes. Stem, surface, or flush mounted.

Type 1010

Aluminum in 4$^1/_2$" and 6" sizes; cast iron in 8$^1/_2$", and 12", friction steel ring. Black epoxy coated. Stem, surface, or flush mounting; lower and back connection.

Type 1017/1187

Aluminum case in 4$^1/_2$", 6" and 8$^1/_2$" sizes, with steel ring hinged at top, retained by a clamp screw at the bottom. Case and ring are black epoxy coated. Flush mounted, back connection only.

ELECTRONIC CONSOTROL INSTRUMENTS

UNIVERSAL CASE INSTRUMENTS ELECTRONIC

PNEUMATIC CONSOTROL INSTRUMENTS

UNIVERSAL CASE INSTRUMENTS PNEUMATIC

SPECIAL PURPOSE INSTRUMENTS

PANELS & CABINETS

DIGITAL SYSTEMS

PRESSURE

FLOW

LIQUID LEVEL

TEMPERATURE

SPEED, POSITION, ELECTRIC MEASUREMENT

WEIGHT, FORCE, TORQUE, DENSITY

HUMIDITY & MOISTURE

PRODUCT ANALYSIS

TELEMETERING

VALVES, POSITIONERS, OPERATORS

ACCESSORIES

ENGINEERING DATA

PRIMARY DEVICES

Fig. B5158

Fig. B5517

Fig. B5159

Fig. B5160

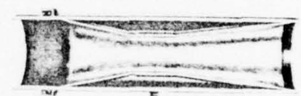


Fig. B5162

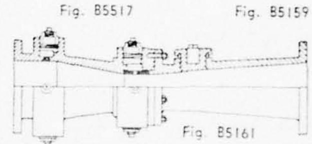


Fig. B5161

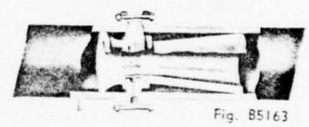


Fig. B5163

Flow through a primary device results in a differential pressure, inferential of flow rate, across the device. This pressure is measured by the measuring elements and transmitters described on pages B15–B23. Selection of a primary device is determined by: (1) physical characteristics of the fluid; (2) maximum rate of flow; (3) static pressure; (4) size of pipeline; (5) allowable over-all pressure loss.

ORIFICE PLATES

Recommended for clean fluids only. Have more advantages—and suitable for more applications—than any other primary device.

The square-edged orifice plate—B5158—with identification tab for use with raised-face flanges, is furnished in stainless steel, Monel and other materials, to meet ASME and AGA standards. Orifice may be concentric, eccentric, segmental, and quadrant edged. Available, without identification tab, for use with tab-type holding ring in ring-type-joint flanges, and orifice fittings. Orifice flanges, holding rings, orifice fittings also available.

FLOW NOZZLES

Provide greater flow capacity and constant discharge coefficient over a wider range of flow rates than orifice plates. Widely used for steam flow; also for fluids containing moderate amounts of solids in suspension.

Forged flow nozzles are available in either flange-type—B5159—or welding-ring-type (not shown) for high pressure and high temperature applications. Furnished to ASME standards in carbon steel, 304 stainless steel, chrome molybdenum and other materials. Fabricated, flange-type flow nozzles, in 304 stainless steel, are also available.

FLOW TUBES

Recommended for water, sewage, sludges, slurries, chemicals, steam trade wastes, air and gases. Tube throat is smooth curve with no exposed sharp edges or channels to clog.

Flow tube—B5517—features minimum pressure loss with large differential pressure for a given discharge. Also constant flow coefficients down to low Reynolds numbers and velocities for accuracy to within ±1.0 percent of actual flow rate (±0.5 when laboratory calibrated).

Tubes available with flanged ends, with holding flange for insertion between flanges, or for in-line welding. Materials include cast iron, Meehanite, forged steel, stainless steel, Polyester fiber glass, as well as special materials.

VENTURI TUBES

Recommended for fluids containing large amounts of suspended solids, for low net pressure loss.

Type PVW—B5161—is available with standard recovery cone; or with long recovery cone for lowest pressure loss of any venturi form. Manufactured to AWWA specifications.

Modified forms of Type PVW, multi-tap or single-tap, and with clean-out valves, manual flushing or continuous purge, are available for sewage (Type PVS) and sludge (Type PVSL) flow measurement.

Type PVF—B5162—is lighter, less expensive than Type PVW. Fabricated tube is welded inside section of steel pipe. Has conventional-form cones, and throat of stainless steel; plain, spigot, or flanged ends. Supplied with piezometer taps, as shown, or with single taps at entrance and throat.

One-piece—fabricated or bar stock—modified venturi tubes, without piezometer rings, are also available in small sizes, generally below 6-inch, for slurries and fluids containing solids.

Type PVI—B5163—is used where space is insufficient for standard-form tube. Insert tube has integral holding ring for flange mounting, with single entrance tap, either external on the pipe—as shown—or integral with the throat tap in the holding ring (not shown). Cast iron body and recovery cone, bronze throat liner, standard through 20-inch sizes; cast iron body, steel plate recovery cone, standard for sizes above 20 inches. Also available in stainless steel.

PITOT TUBES

Recommended where only comparative measurements are required, when fluid is clean, line is large, and velocity is high. For accurate quantitative measurements, Pitot tubes must be calibrated in the line.

The adjustable-type Pitot tube—B5160—is installed through a corporation cock or gate valve for insertion or removal while line is under pressure. Available in brass or stainless steel. Also supplied in fixed type, where insertion or withdrawal, with line under pressure, is not required.

ELBOW TAPS

An existing pipe elbow becomes a primary device when pressure taps are employed under prescribed conditions. Elbow taps are easily and inexpensively installed by the user, and though not as accurate as other primary devices, provide a convenient method of repeatable flow measurement for control purposes.

d/p CELL TRANSMITTERS FOR ACCURATE RELIABLE FLOW MEASUREMENT

FEATURES

THE DIAPHRAGM CAPSULE

The design of the differential pressure sensing element makes it possible to use a light, completely welded stainless steel, twin diaphragm capsule, sensitive to the slightest change in differential pressure. One 316 stainless steel diaphragm is seam-welded to each side of a 316 stainless steel back-up plate. Temperature-stable silicone fluid fills the space between diaphragms and plate. Very small holes drilled through the plate allow fluid to be transferred from one side of the capsule assembly to the other. This construction damps out effect of unwanted line noise. Position of connection holes parallel to capsule makes it impossible for mechanic's screwdriver to puncture diaphragm.

FAIL-PROOF OVERRANGE PROTECTION

Convoluted surface of the diaphragm fits the matching back-up plate. No need for "O"-ring seals. When overrange occurs and silicone fluid is displaced from one side of the capsule to the other, either diaphragm is supported by the plate and cannot be distorted. Recalibration not necessary.

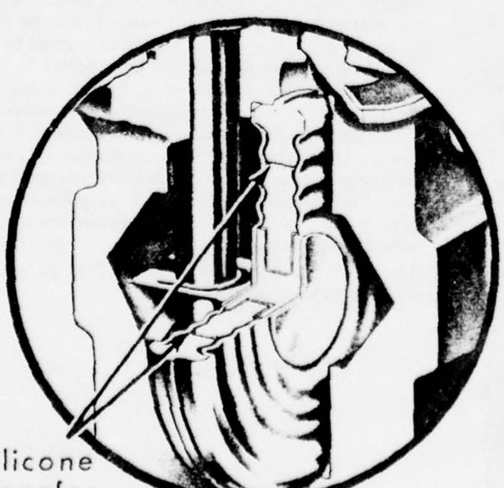


Fig. B7461. Close-up of Diaphragm Capsule.

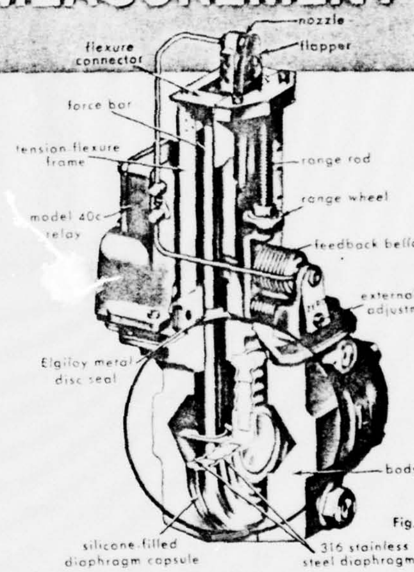


Fig. B6434

SIMPLE RANGE AND ZERO ADJUSTMENTS

Range rod and range wheel (Figure B6434) provide continuous wide-range adjustment. Externally accessible zero-adjustment screw is protected by a sliding clip to discourage tampering (Figure B6434). No external or internal damping adjustment necessary — damping cannot be maladjusted through error or tamper. Permanent damping is designed to provide faithful output reproduction of measured differential.

ALL-METAL CONSTRUCTION

Assures lifetime, virtually maintenance-free operation. An Elgiloy metal disc acts as a leak-proof seal between cell body and transmitter mechanism. Other measuring parts exposed to process liquid can be either plated carbon steel, 316 stainless steel, or Monel metal. Optional diaphragm capsule materials are available for special corrosive applications. The transmitting mechanism has a weather-proof housing continuously purged with clean, dry operating air.

The basic components — body, force-balance transmitter system, and air connection block — are separate units. Process piping stresses are confined to body, air piping stresses to the air connection block. Force-balance system is completely isolated from exterior forces.

There is essentially zero volume displacement with Foxboro d/p Cell Transmitters — no condensing or sealing chambers are necessary.

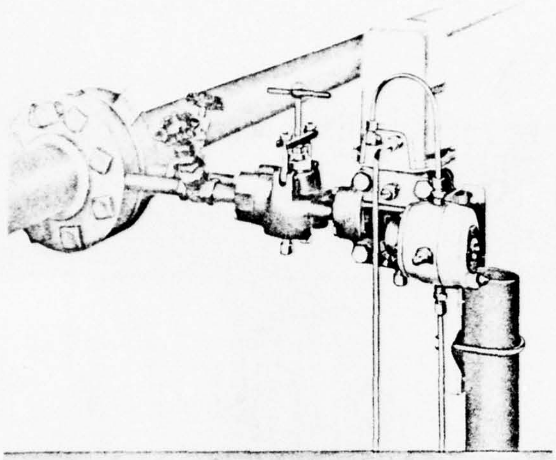


Fig. B6436. Typical Installation of d/p Cell Transmitter for Liquid Measurement.

SIMPLICITY OF INSTALLATION

Transmitter may be installed in any position. High and low pressure connection taps are at both ends of body for optional connection. The instrument is designed for simple close-coupling at the point of measurement (Figure B6436).

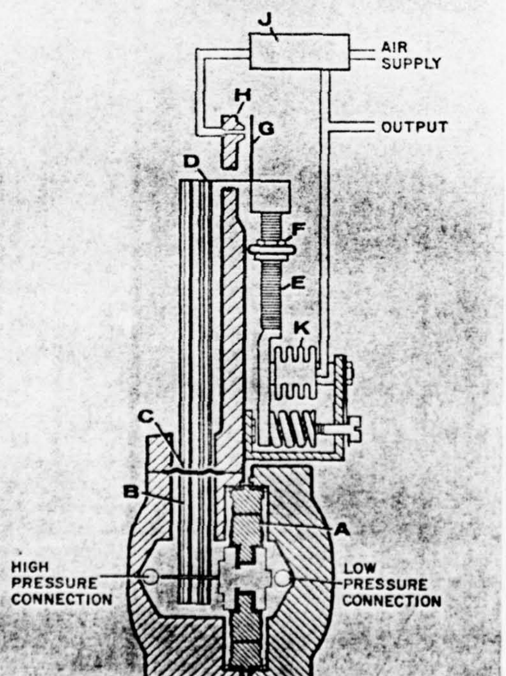


Fig. B7503

PRINCIPLE OF OPERATION

Pressure is applied through the high and low pressure connections to opposite sides of silicone-filled twin-diaphragm capsule (A). Difference between pressures exerts force at lower end of force bar (B), which is balanced by a simple lever system consisting of force bar (B), range rod (E) and flexure connector (D), with Elgiloy metal disc (C) acting as a fulcrum together with range wheel (F). Range wheel adjusts the measurement span to any value within the limits of the diaphragm capsule. The force exerted by this capsule is opposed through the lever system by feed-back bellows (K). In operation, flapper nozzle (H) detects the slightest variation in forces developed at the capsule and effects a counterbalancing of these changes by altering input pressure at relay (J), simultaneously changing feed-back bellows balancing pressure. Continuously adjusting bellows pressure maintains a state of force-balance between bellows and twin-diaphragm capsule.

The result is a pneumatic signal of 3-15 psi proportional to differential pressure.

Smith Meter Systems Division
Geosource Inc.

BULLETIN 2.0.3.8

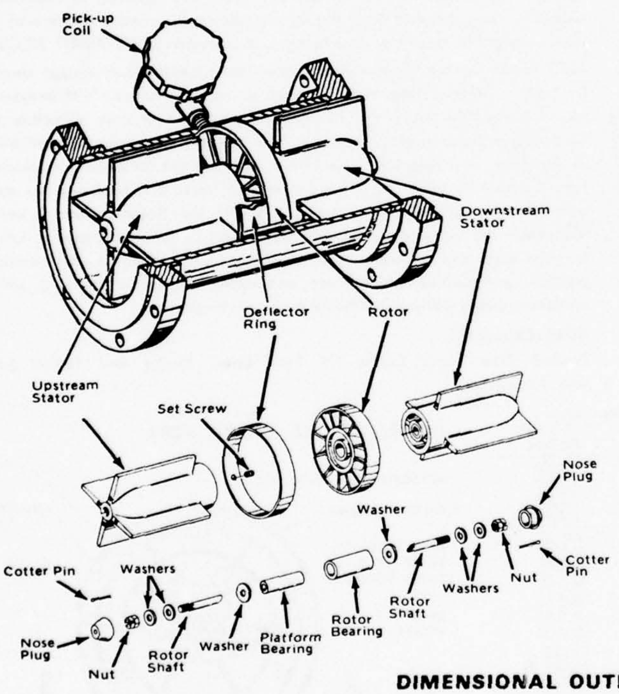
SPECIFICATIONS

18" SENTRY SERIES TURBINE METER

GEOSOURCE

DECEMBER 1971

ASSEMBLY



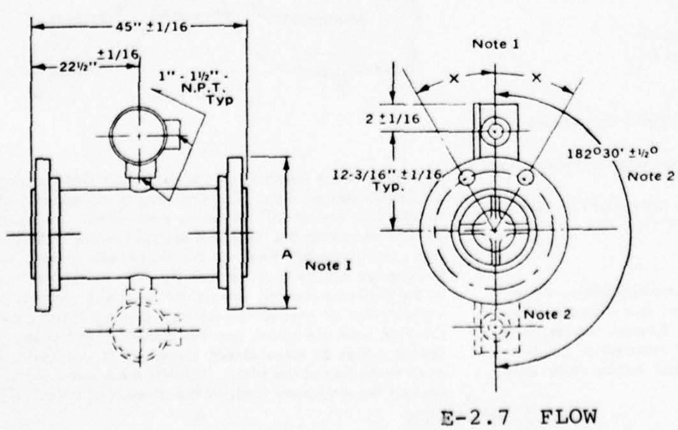
MATERIALS OF CONSTRUCTION

PART	MODEL CA	SA	CS	SS
HOUSING	Carb. Stl.*	304 SS	Carb. Stl.*	304 SS
FLANGES	Carbon Stl. or 304 SS			
STATORS	356T6 Aluminum		316 Stainless	
PLUGS	304 Stainless		304 Stainless	
DEFLECTOR RING	Carbon Steel Lubrited		304 Stainless	
SET SCREW	Carbon Steel		304 Stainless	
ROTOR	304 Stainless Steel			
ROTOR INSERTS†	Hy-Mu 80			
SHAFT	304 Stainless Steel			
NUTS	Cadmium Plated Steel			
BEARINGS, WASHERS	883 Tungston Carbide			
SHAFT WASHERS	Chrome Vanadium Steel			
COTTER PINS	300 Series Stainless Steel			

* Lubrited and Electro-film Coated

† Located on Rotor Rim

DIMENSIONAL OUTLINE



Flange Rating A.N.S.I.		150#	300#	400#	600#	900#
"A" Dim.		25"	28"	28"	29¼"	31"
App. Ship. Wt. (lbs.)	Model CA & SA	1200	1520	1590	1800	–
	Model CS & SS	1350	1670	1740	1950	–

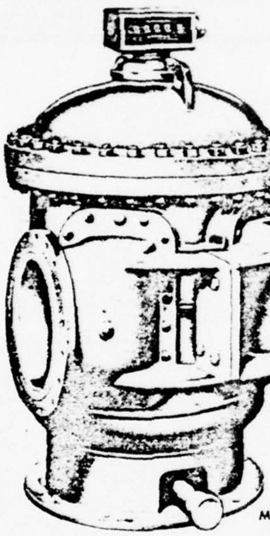
Notes:

1. Meter pressure rating and flange data per ANSI.
2. Multiple pickup coils and condulets when specified. 2nd coil 90 electrical degrees from base coil.
3. *Shipping weights include 20% packing weight.*

Bulletin 1.5.4.1

K12-S3, S5, S6, S7 and M16-S3, S5 S6, METERS

September 1974



Model M16-S3
With large
numeral counter

The K 12-S3, S5, S6, S7 and M16-S3, S5, S6 meters are designed for high capacity service on petroleum pipe lines and at tanker loading and unloading facilities for rates from 6000 up to 12,500 barrels per hour. They are dual-case meters with the metering unit installed in a welded steel housing.

With the Smith Meter principle, illustrated below, the flow of liquid is literally undisturbed while it is being metered. Since energy is not wasted in arresting liquid velocity, slippage is reduced to a minimum, resulting in GREATER ACCURACY. Low pressure drop due to streamlined flow and a minimum of friction means long life and low maintenance, thus assuring SUSTAINED ACCURACY.

A. O. Smith Double Case Meters follow the original rotary design developed by Smith. The metering unit is installed in an outer housing with pressure balanced across the metering unit thus eliminating inner case distortion due to operating pressure and piping strain. The double-case construction affords ease of servicing. It is possible to remove a metering unit for inspection, cleaning or repair simply by removing the outer housing cover and removing the metering unit. The measuring unit is removed vertically, thus liquid spillage is kept to a minimum. The ease of removal of the metering unit is conducive to low maintenance costs and greater overall accuracy as the off-stream time encourages periodic preventitive maintenance inspection. Complete metering units are interchangeable between different meter housings.

APPLICATIONS

Product Pipe Lines; Crude Oil Pipe Lines; Barge and Tanker Loading and Unloading.

SPECIFICATIONS

NORMAL RATED CAPACITY

		Available Registration Cubic Meters Per Hour	U. S. Barrels Per Hour
K12-S3, S5, S6 and S7	Maximum	950	6,000
	Minimum	190	1,200
M16-S3, S5 and S6	Maximum	2000	12,500
	Minimum	400	2,500

WORKING PRESSURE	275 PSI	19 Kg Cm^2	K12-S3
	300 PSI	21 Kg $3m^2$	K12-S5
	720 PSI	50 Kg $3m^2$	K12-S6
	1440 PSI	100 Kg Cm^2	K12-S7
	275 PSI	19 Kg Cm^2	M16-S3
	300 PSI	21 Kg Cm^2	M16-S5
	720 PSI	50 Kg Cm^2	M16-S6

FLANGES	12"	150 lb.	ANSI	K12-S3
	12"	300 lb.	ANSI	K12-S5, S6
	12"	600 lb.	ANSI	K12-S7
	16"	150 lb.	ANSI	M16-S3
	16"	300 lb.	ANSI	M16-S5, S6

MATERIALS OF CONSTRUCTION*

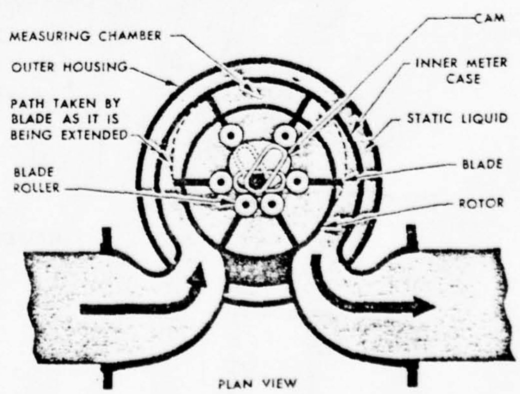
Meter Housing—welded steel construction
Inner Meter Case—close grained cast iron
Rotor—close grained cast iron
Block—close grained cast iron
Bearings, Shaft and Pins—stainless steel with phenolic
Cam and Gears—steel
Blades—anodized high tensile aluminum alloy with wear strips
Bushings—sintered iron

*Some internal meter parts are treated with ARMORLOY, a SOLID FILM LUBRICANT with certain corrosion resistant properties.

ADJUSTMENT

Dry, accessible calibration is made in extremely fine increments with any A. O. Smith adjustment device. These adjusting devices are protected from dirt and foreign matter, and may be sealed against unauthorized tampering. Various units are available for both gross and temperature compensated registration.

PRINCIPLE OF OPERATION



PLAN VIEW

The rotor, which revolves on stainless steel ball bearings, has six evenly spaced slots. The slots control the position of three blades that are at 60° angles to each other. As liquid flows through the meter, the rotor and blades revolve around a fixed cam. Ball bearings fixed to the blades roll around the cam, causing the blades to move radially. The successive movement of the blades, outwardly toward the case wall, forms a measuring chamber of precise volume between the blades, the rotor, the case wall, the cover, and the bottom of the case. A continuous series of these closed chambers is produced, six for each revolution of the rotor. Neither the blades nor the rotor contact the stationary walls of the measuring chamber.

SPECIFICATIONS — "KIT" ACCESSORIES

TYPE OF KIT CLASS		CLASS A	CLASS B	CLASS C*
Maximum pressure		3 psig	3 psig	3 psig
GUIDE WIRE AND SPRING ASSEMBLY		MATERIALS OF CONSTRUCTION		
Housing Cap, Tube, Retainer and Washer		Steel		
Spring		Spring Steel		
Guide Wire		Stainless Steel		
PULLEY ASSEMBLY		MATERIALS OF CONSTRUCTION		
Housing & Cover		Cast Aluminum	Cast Aluminum	Nodular Iron
Pulley		Delran	Cast Aluminum	Cast Aluminum
Bearing		Teflon		
Shaft		Stainless Steel		
Floats	Floating Roof Tanks	17¼" Dia. Stainless Steel Pan Float		
	All Other Tank Types	11-7/8" Dia. Polyethylene Float (below 3 psig)		
	Tanks from 3 thru 50 psig	17¼" Dia. Stainless Steel Pan Float		

*50 psig service available for kit No. 12C and 14C

"INSTALLATION KIT" NUMBER EXPLANATION

KIT NO. X X

TANK TYPE AND TYPE OF ENTRY — TYPE OF KIT CLASS

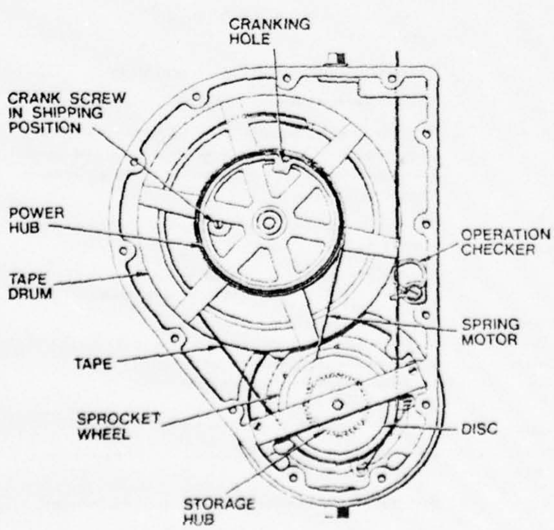
KIT SELECTION PROCEDURE

1. Determine "Kit" number by referring to tank configuration and type of installation shown on pages 4 thru 9.
2. Determine "Kit" Class by requirement of stored product and tank pressure.

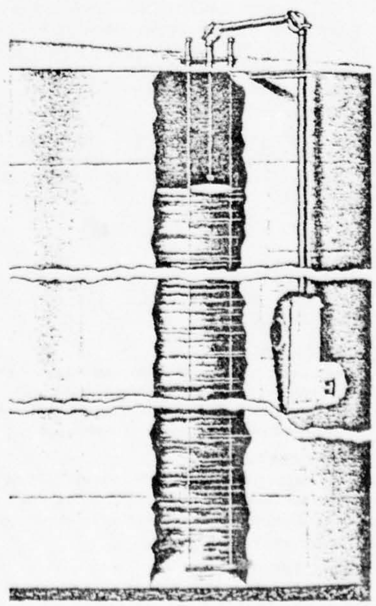
EXAMPLE

KIT NO. 2 A

CONE ROOF TANK FOR INSTALLATION THROUGH TANK SHELL — KIT CLASS FOR BELOW 3 PSIG SERVICE



SCHEMATIC OF TAPE AND CONSTANT FORCE MOTOR ASSEMBLY



TYPICAL LEVEL GAGING INSTALLATION OF MODEL 92020

Shand & Jurs

MODEL 92020

AUTOMATIC TANK LEVEL GAGE

PRODUCT DATA SHEET 92020

DESCRIPTION

The Shand & Jurs Model 92020 Automatic Tank Level Gage is a float actuated tape driven gage, and by means of a digital counter indicates float travel accurately to 1/16 inch. Model 92020 meets all the specifications and recommendations of the American Petroleum Institute in accordance with API Bulletin 2509B.

Pioneers in automatic tank gaging, GPE Controls, Inc., has enjoyed a preeminent position for well over 30 years with Shand & Jurs gaging systems.

A stainless steel tape, accurately perforated, rotates an aluminum sprocket wheel with stainless steel pins, which in turn drives the digital readout counter. A stainless steel constant force motor maintains tension on the float throughout the gaging range. Bearing loads are well distributed through filled fluorcarbon bushings rotating on polished stainless steel shafts.

Local readout is by means of digital counter featuring large black numerals on a white background. Remote reading is added by simply removing the counter housing cover, installing coupling, and bolting transmitter in its place. Gage calibration is quick and easy . . . loosen screws and swing open access plate; then, simply rotate large inch wheel until counter wheels are set. This is the fastest, and most positive calibration available on any float actuated counter type gage.

Choice of materials, rugged construction and counter housing sealed from gage head permits application of this gaging system to a wide variety of environmental conditions. Optional feature on gage head includes a h d crank for manually raising and lowering the float, an operational checker for manually jogging the tape to insure a "free" system, provision for high and low level limit switches.

To facilitate easy ordering, complete accessory kits are available for all standard and most special tank configurations and cover a broad selection of materials.

FEATURES

■ ACCURATE
Large digital readout driven by accurately perforated tape provides non-ambiguous and consistant data to meet API standards of accuracy.

■ RELIABLE
Long contact arc of tape on sprocket and non-jamming construction of rotating parts assure reliability. Constant tension on float results in accurate reading; also, ventilated counter housing is non-fogging.

■ VERSATILE
Low copper aluminum body, carefully selected materials for internals, optional feature nd accessories make this system adaptable to most products and storage vessels.

■ ECONOMICAL
Limited number of mounting brackets minimize installation cost. Complete gaging system "kits" for each installation further reduce cost.

GROUND READING TANK GAGE

ROOF READING TANK GAGE

MODEL 92020 AUTOMATIC TANK GAGE

HOW TO ORDER

Specify:

1. Model 92020 Automatic Tank Level Gage.
2. Type of service: Normal, ammonia, or severe.
3. Gage head only, gage head fitted for limit switch*, gage head with hand crank or gage head with hand crank and fitted for limit switch*. With or without Operation Checker.
4. Type of calibration: feet and inches, decimal feet or meters.
5. Type of readout: a. innage or outage
   b. maximum tank height
6. Type of installation:
   a. Gage only (without tape for ground reading)**
   b. Ground reading (fixed roof tank)
   c. Ground reading (floating roof tank)
   d. Roof reading
   e. Turbulent tank (ammonia, LPG)
7. Description of fluid to be gaged including pressure, temperature, specific gravity, etc.
8. Additional accessories required, specify in detail.

*Limit switch must be ordered separately.

**For roof reading, specify.

CONTROLLING MATERIALS ON THE MOVE....
PROCESS CONTROLS • GUIDING EQUIPMENT • TANK FITTINGS • MARINE TRANSPORTATION

Shand & Jurs

MODEL 92302

LIQUID LEVEL INDICATOR

PRODUCT DATA SHEET 92302

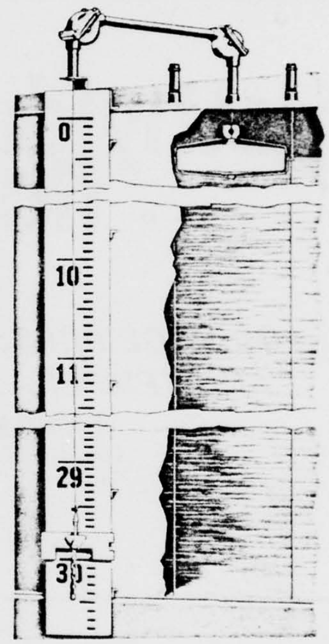
DESCRIPTION

The Shand & Jurs Model 92302 Liquid Level Indicator is a reliable and inexpensive float actuated level gaging system, which utilizes a sturdy aluminum or redwood indicator board.

The target on the indicator board is accurate to within one inch. Large black numerals on a white background make the readout plainly visible. The indicator board is available with graduations in feet and inches or with graduations in meters. Half travel targets are available for special installations such as below ground tanks.

A choice of various materials is available which permits application of this gaging system to a wide variety of environmental conditions. A liquid seal is available for vapor tight installations to retain tank vapor space pressure and vacuum within the range accommodated by vacuum/pressure breather valves with standard settings. The liquid seal also protects gage board from corrosive tank vapors.

Guide wire assemblies and an anchor bar are recommended for tanks over 12 feet high or where product turbulence exists. The Model 92302 Liquid Level Indicator is also available with limit switches to provide for high and/or low level alarms, pump start and stop control, or a variety of other signaling functions.



LIQUID SEAL

HOW TO ORDER

Specify:

1. Model 92302 Liquid Level Indicator
   a. Type of tank (if other than cone roof)
   b. Type of service
2. Type of board material
3. Feet and inches or meter and decimeters calibration
4. Height of tank
5. Additional accessories required, Limit Switches, inspection frames, etc. Specify in detail.

FEATURES

■ **ECONOMICAL**
Low cost and easy installation makes this an ideal solution to simple gaging problems.

■ **VERSATILE**
Standard materials suitable for most services. Components of special materials readily available.

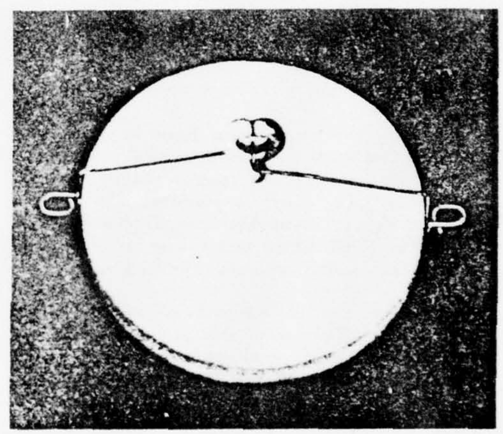
■ **ACCURACY**
Construction affords accuracy to the nearest inch.

■ **RELIABLE**
Non-jamming construction of movable parts assures reliability.

THE COMPANY THAT'S INVOLVED ... COMBUSTION CONTROLS • GUIDING SYSTEMS
PIPELINE CONTROLS • TANK FITTINGS • MARINE SYSTEMS

BULLETIN 9399-11000

polyethylene float



FOR WIDE PRESSURE AND TEMPERATURE RANGES. . .

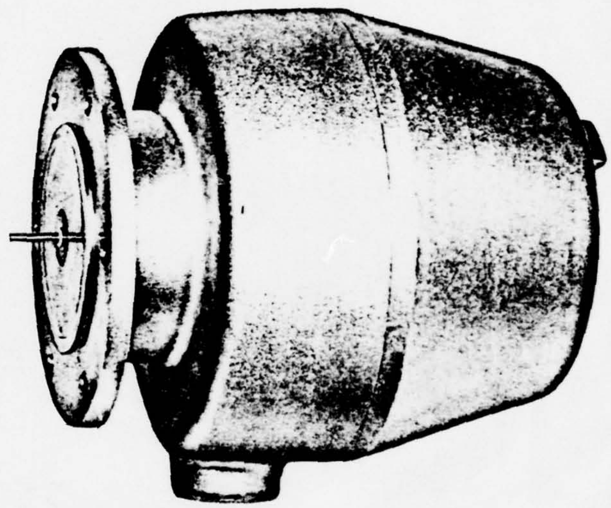
- REPLACES COSTLY STAINLESS STEEL FLOATS
- IDEAL FOR CAUSTICS, ACIDS AND VOLATILE LIQUID ENVIRONMENTS
- ADAPTS TO PRESENT GUIDE WIRE FLOAT GAGES
- CORROSION RESISTANT

SPECIFICATIONS

Materials:	High Density Polyethylene and Glass Filled Polypropylene
Pressure Range:	3 psig Maximum
Temperature Range:	−20° to 215° F
Specific Gravity Range:	.5 to 1.3
Weight:	4 Pounds

GPE CONTROLS

PRODUCT BULLETIN LB-260-110



CURRENT TRANSMITTER

DESCRIPTION

The Model X31420 Current Output Transmitter is a potentiometer type transmitter which transmits field information to a remote point. This transmitter is intended primarily for coupling to tape drive float type gages.

Contained in a weather and explosion proof housing, the transmitter uses one 2,000 ohm potentiometer which is driven through a gear reduction of the input shaft. The output is a current which is proportional to the position of the wiper in the potentiometer. This current output signal is transmitted to a compatible receiver.

High and low level alarm switches are available to provide safety during loading or discharge of product. Alarm switches can be acutated within plus or minus one foot of desired range.

SPECIFICATIONS

INPUT POWER:

Transmitter: 30 V.DC ± 1% at 40 ma
60 V.DC ± 1% at 75 ma

Alarm Switches: 125/250 VAC/28 V DC at 2.5 amp

INPUT SIGNAL: Shaft position

OUTPUT SIGNAL: 4-20 ma DC
10-50 ma DC

OUTPUT LOAD IMPEDANCE: 10 to 500 ohms

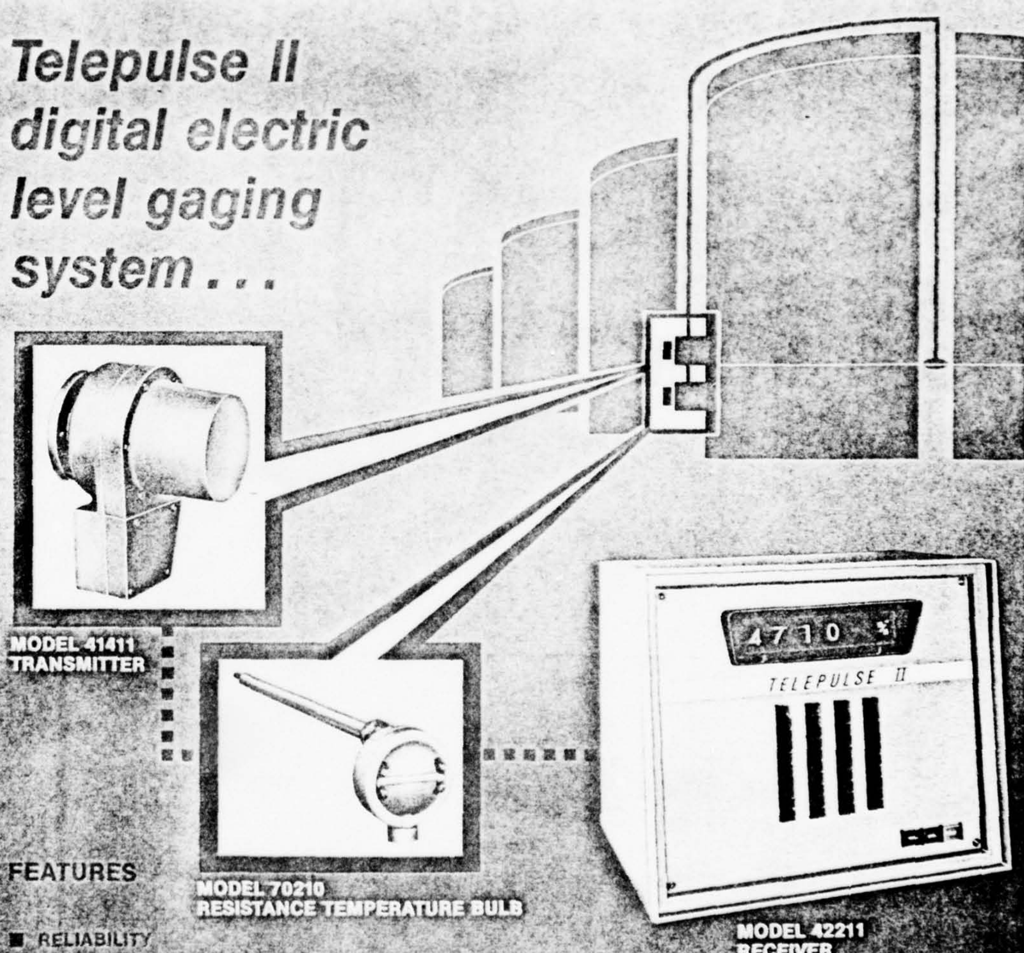
RANGE: 20 to 120 feet (10 foot increments)

WIRING: Four conductors

GPE CONTROLS

PRODUCT DATA SHEET RG-211

Telepulse II digital electric level gaging system . . .



FEATURES

- **RELIABILITY**

Solid state electronics throughout. Plug-in printed circuit boards for greater dependability.

- **VERSATILITY**

Provisions for Data Logger and/or computer interfacing.

- **FAST RESPONSE**

Temperature readout in 250 milliseconds. Level readout in 2 to 5 seconds on standard system.

- **LOW MAINTENANCE**

No contact magnetic pick-up coils eliminate failure due to worn brush and disc contacts.

- **EXTREME ACCURACY**

Transmitter is accurate to fine increments [illegible] range. Receiver level readout is to [illegible] 1 MM. Temperature readout is accurate [illegible] degree.

- **LOW INSTALLATION COST**

Modular packaged electronics with direct or matrix wiring for reduced wire count.

DESCRIPTION

The Telepulse II Level Gaging System provides liquid product storage facilities with the most reliable and accurate remote measurement system available. GPE's Telepulse II system has maintained a reputation for extreme dependability. This is why there are more than 5,000 installations in operation.

Continued modernization, physical expansion and computerized operation of present facilities demand the most reliable and proven gaging system on the market. Telepulse II is designed to keep in step with these requirements.

The Telepulse II Digital Electric Gaging System consists of two basic components, a Model 41411 Level Transmitter and a Model 42211 Receiver.

The Model 41411 Transmitter mounts directly to a float-type level gage and digitally encodes shaft position. The Transmitter utilizes magnetic pick-up coils for operation and, therefore, no contact is required. This principle of inductance provides for reliability, durability and extreme accuracy.

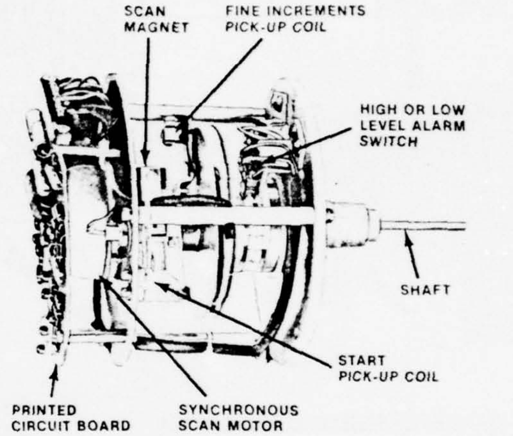
When reading is required, a truly synchronous scan motor drives a magnet at a constant speed past the pick-up coils, inducing a voltage pulse. Two pulse signals are provided for: one for the fine increments (inch, decimal foot, or millimeter), and the other for unit increments (foot or decimeters).

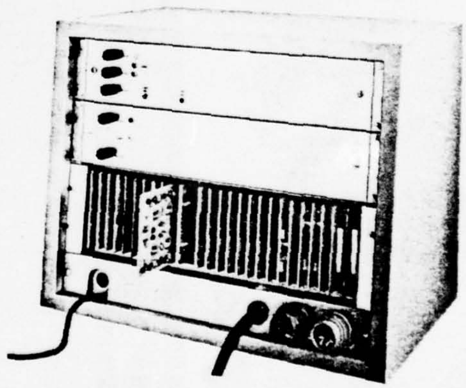
The maximum duration between pulse signals is 100 milliseconds. These signals are transmitted in parallel to the Model 42211 Receiver located at a remote point.

The Model 42211 Receiver provides for digital display of level and temperature readings. Each tank is positively identified with a separate pushbutton. A reading is displayed only if proper tank is selected and function button is pushed. Function buttons are marked for level and temperature. (Data Logger is optional.)

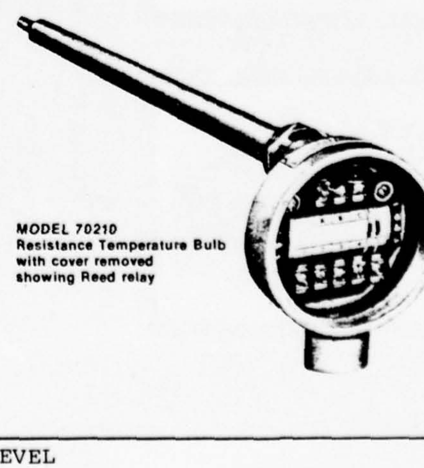
The Receiver provides for optional connections for a Data Logger, which can be added at any time. In addition, provisions for computer interfacing is readily accommodated. The output for this option is 4-line BCD from dry contacts. The Telepulse II Receiver can accommodate the most complex computer programs, such as, high speed scanning of an entire storage facility during filling or unloading procedures to obtain up-to-date information on high and low level readings. Only slight modification to standard circuitry is necessary.

The Model 42211 Receiver is available in a standard sloping desk type console, which accommodates up to 100 points. For larger storage tank facilities, the Receiver electronics are easily expanded and can be adapted to sophisticated supervisory control systems.

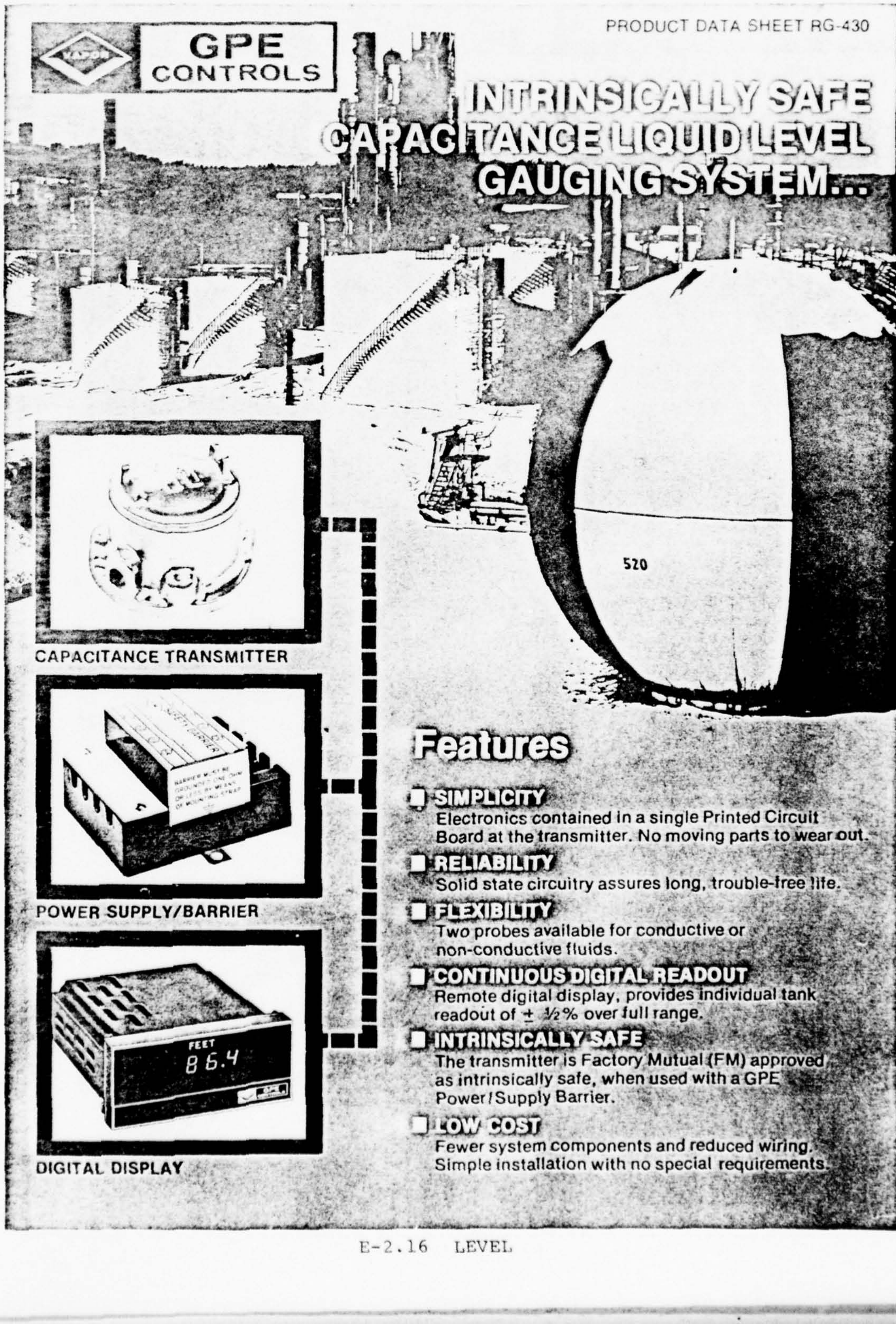




Model 42211 Receiver with back panel removed showing solid state electronics with Data Logger Pin Connectors. Simple plug-in printed circuit boards for fast servicing.



MODEL 70210
Resistance Temperature Bulb with cover removed showing Reed relay



PRODUCT DATA SHEET RG-430

GPE CONTROLS

INTRINSICALLY SAFE CAPACITANCE LIQUID LEVEL GAUGING SYSTEM...

CAPACITANCE TRANSMITTER

POWER SUPPLY/BARRIER

DIGITAL DISPLAY

Features

- **SIMPLICITY**
  Electronics contained in a single Printed Circuit Board at the transmitter. No moving parts to wear out.
- **RELIABILITY**
  Solid state circuitry assures long, trouble-free life.
- **FLEXIBILITY**
  Two probes available for conductive or non-conductive fluids.
- **CONTINUOUS DIGITAL READOUT**
  Remote digital display, provides individual tank readout of ± ½% over full range.
- **INTRINSICALLY SAFE**
  The transmitter is Factory Mutual (FM) approved as intrinsically safe, when used with a GPE Power/Supply Barrier.
- **LOW COST**
  Fewer system components and reduced wiring. Simple installation with no special requirements.

GPE CAPACITANCE GAUGING FOR CONI

DESCRIPTION

The Model 31430 is a continuous level gauging system, using a capacitance probe. The principle of measuring the level is based on the dielectric change between liquid and air, which provides a capacitance signal proportional to the tank liquid level.

The Capacitance Liquid Level Gauging System can be applied to both conductive and non-conductive fluids. Only two basic components are necessary to provide accurate and reliable level readings. A transmitter, which mounts directly to the storage tank, and a digital display located up to 1000 feet away, which displays a continuous level reading.

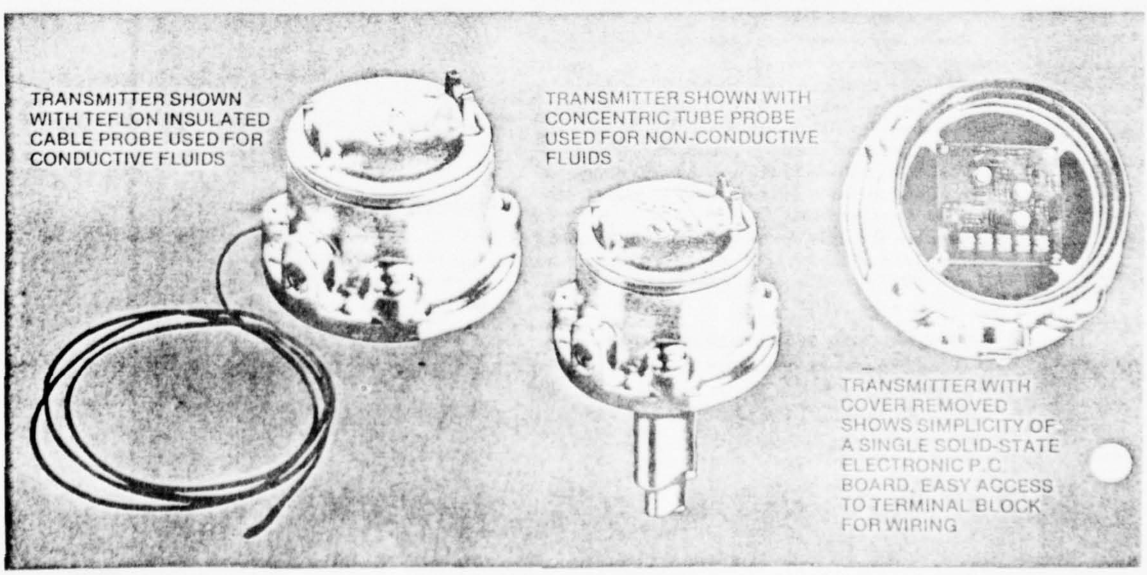
GPE's Capacitance Gauging System is available in two model options. For conductive fluids, such as water, wines, acids or most water-based products with a low dielectric constant, a teflon insulated cable probe is used. For non-conductive fluids, such as gasoline or petroleum based liquids with a high dielectric constant, a concentric tube probe is available.

The teflon insulated probe is normally anchored to the bottom of the tank and extends the full length of the tank and is terminated in the weatherproof transmitter housing. The Model 31430 Transmitter contains within its compact housing a highly reliable solid-state printed circuit board. This single P.C. board contains the entire electronics required to measure the capacitance of the probe and transmit this signal to the remotely located digital display.

To meet intrinsically safe requirements, the transmitter receives its power from a Power Supply/Barrier. The entire system, when connected per specification, is approved by Factory Mutual for Intrinsically Safe operation in Class I, Division 1, Group D hazardous areas.

The conductive probe provides an accuracy of ± ½% over full range. To maintain this accuracy, it is essential that the probe is linear to the tank and the fluid measured is of conductive properties.

The concentric tube probe used for non-conductive liquids is rated at ± ½% accuracy, and is installed in a rigid vertical fashion from tank bottom to tank top. It is available in 10 foot sections which are joined together to form the length required. For extremely high tanks or turbulent tanks, insulated support brackets are necessary to avoid probe damage or non-linear output.



ELECTRONIC CONSOTROL INSTRUMENTS

UNIVERSAL CASE INSTRUMENTS ELECTRONIC

PNEUMATIC CONSOTROL INSTRUMENTS

UNIVERSAL CASE INSTRUMENTS PNEUMATIC

SPECIAL PURPOSE INSTRUMENTS

PANELS & CABINETS

DIGITAL SYSTEMS

PRESSURE

FLOW

LIQUID LEVEL

TEMPERATURE

SPEED, POSITION, ELECTRIC MEASUREMENT

WEIGHT, FORCE, TORQUE, DENSITY

HUMIDITY & MOISTURE

PRODUCT ANALYSIS

TELEMETERING

VALVES, POSITIONERS, OPERATORS

ACCESSORIES

ENGINEERING DATA

BUOYANCY TRANSMITTERS
For Liquid Level or Density Measurement

Fig. B5692
Model 17B4 Pneumatic Buoyancy Transmitter for Top-of-Vessel Mounting.

Fig. B5693
Model 617B4 Electronic Buoyancy Transmitter for Top-of-Vessel Mounting.

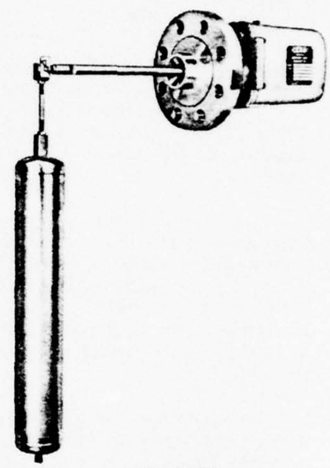


Fig. B5694
Model 17B6 Pneumatic Buoyancy Transmitter for Side-of-Vessel Mounting.

These force-balance transmitters measure and transmit—pneumatically or electronically—liquid level, interface or density by sensing the buoyant force exerted by a displacer element. They can be used in vented, pressurized, or evacuated vessels.

Level measurements are made as the surface liquid varies over the length of the displacer element. Displacers are available in lengths from 14 to 120 inches, or longer where required.

Density measurements are made with the displacer element completely submerged.

Level and density change caused by variations in buoyant force are converted to 3-15 psi or 10-50 ma d-c signals proportional to measurement. Signals are transmitted to standard Foxboro pneumatic or electronic CONSOTROL receivers which can be mounted up to several hundred feet away (pneumatic) or several thousand feet away (electronic).

There are four basic transmitter models in the series: Models 17B4 Pneumatic and 617B4 Electronic; and Models 17B4 Pneumatic and 617B6* Electronic.*

OPEN OR CLOSED VESSEL MEASUREMENT Buoyancy transmitters can be applied to level or density measurement in vented, pressurized, or evacuated vessels with unsurpassed repeatability and accuracy.

*Where process requires, either of these transmitters can be installed in a vertical leg external from the vessel.

MAINTENANCE-FREE OPERATION One-piece flexures throughout—no knife edge pivots, no wear. Eliminates routine maintenance. Side-of-vessel version incorporates flush flexure-seal at flange face—no collecting pockets for liquid that tend to solidify or compact.

HIGH PERFORMANCE FORCE-BALANCE OPERATION True force-balance operation (motion of element is less than 0.015 inch for full measuring span) means no element travel error, virtually no hysteresis, excellent repeatability and accuracy, minimum dead band.

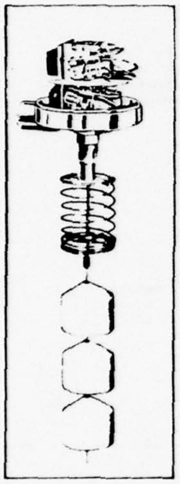
PROCESS PROVEN TRANSMITTER This is the widely accepted, reliable Foxboro force-balance d/p CELL Transmitter mechanism. Only one calibration procedure for complete line of pneumatic and solid-state electronic force-balance transmitters for pressure, flow or liquid level. Common parts minimize inventory requirements.

IN-PROCESS CALIBRATION Transmitter can be calibrated simply by suspending weights from the upper force bar. Simple and accurate calibration.

DISPLACER TYPE LIQUID LEVEL CONTROLS MAGNETIC (PACKLESS)

CAN BE USED FOR DIRTY OR VISCOUS LIQUIDS—NOT AFFECTED BY TURBULENCE—SINGLE OR TWO STAGE OPERATION

MINIMUM SPECIFIC GRAVITY 0.5—MAXIMUM TEMPERATURE 200°F.



Mercoid displacer controls utilize displacers that do not float on the surface of liquids as in conventional float types, but stay submerged. They are not affected by surface agitation. The displacer is solid and not affected by pressure.

OPERATING CHARACTERISTICS

The displacers are suspended on a cable from the armature of a magnetic head control with a spring partially supporting their weight. As the displacers become submerged in a rising liquid, their weight decreases, allowing the spring to move the cable and armature upward, thereby actuating the mercury switches.

The displacers are secured on the cable by clamps. Operating levels can be adjusted by loosening the clamps and moving the displacers up or down the cable as required. The buoyancy produced by the submerging of one displacer is not sufficient to allow the spring to raise the armature; a second displacer must be partially submerged before any operation occurs on a rise. On a drop, however, the cable will not move to its full down position until the level falls to approximately *the mid point of the* lowest displacer (for B190 and 195-7 only). By *spacing the displacers adjustable level operation* and various stage operations can be provided.

CONSTRUCTION—all types. Standard displacers are porcelain (also available of other materials). Stops 316SS. Cable (10 ft.) 316 stainless steel (*longer lengths available*). All enclosures equipped with 3/4" NPT conduit connection. Control case can be rotated 360° to facilitate writing. Terminal block for electrical connections. Standard Flange 4" 125# CI—other sizes and materials available.

ENCLOSURES

GENERAL PURPOSE (NEMA 1). Identified by letter **"G"** in type number as in 195G-4. Heavy gauge steel case finished in charcoal gray.

WEATHER RESISTANT (NEMA 2,3). Identified by letter **"W"** in type number as in 195-4W.

EXPLOSION-PROOF suitable for Class 1, Group C & D; Class 2, Group E, F, & G. NEMA 7, 9, 9A. Identified by the letter **"E"** in type number as in 195-4E.

VAPOR-PROOF—EXPLOSION-PROOF. Identified by letter **"EV"** in type number as in 195-4EV.

SINGLE STAGE OPERATION

SINGLE STAGE CONTROLS WILL OPERATE AT ANY SPECIFIC GRAVITY AND TEMPERATURE LISTED IN TABLES WITH STANDARD FACTORY SETTINGS

SERIES A190—SINGLE STAGE—Fixed Differential

SP* GR	100°F A Max.	100°F A Min.	100°F C	100°F Min. TB	200°F A Max.	200°F A Min.	200°F C	200°F Min. TB
.5	121.5	7-1/2	1-1/2	2-3/4	121	7	1-3/4	3-1/4
.6	122	8	1-1/4	2-1/2	121	7-1/2	1-1/2	2-7/8
.7	122	8-1/2	1-1/8	2-3/8	122	8	1-1/4	2-3/4
.8	122.5	9	1	2-1/4	122	8	1-1/8	2-1/2
.9	123	9	7/8	2-1/8	122	8-1/2	1	2-3/8
1.0	123	9	3/4	2	122.5	8-1/2	7/8	2-1/4
1.1	123	9	5/8	2	122.5	8-1/2	3/4	2-1/8
1.2	123	9-1/3	5/8	1-7/8	122.5	8-1/2	3/4	2-1/8

SERIES B190—SINGLE STAGE—Adjustable Differentials

SP* GR	100°F A Max.	100°F A Min.	100°F C Max.	100°F C Min.	100°F TB Min.	200°F A Max.	200°F A Min.	200°F C Max.	200°F C Min.	200°F TB Min.
0.6	116-1/2	6-1/2	114	6-3/4	2-1/2		NOT AVAILABLE			
0.7	117	7-1/2	115-1/2	6	2-3/8					
0.8	118	8	115	5-1/2	2-1/4	118	8	115	4-3/4	3
0.9	118-1/2	8-1/2	115	5	2-1/8	118-1/2	8-1/2	114-1/2	4-3/8	2-7/8
1.0	119	9	114-1/2	4-5/8	2	119	8-1/2	114-1/2	4-1/8	2-5/8
1.1	119	9-1/2	114-1/2	4-3/8	1-7/8	119	9	114	3-7/8	2-1/2
1.2	120	9-1/2	114-1/2	4	1-3/4	119-1/2	9	114	3-3/4	2-3/8

*Control can be factory set for other specific gravities.

Minimum differential (c) can be reduced, approximately 1" by removing the cable clamp from between the displacers and turning the lower displacer so the flat side is up. If a narrower differential is needed, use a Type A190 control.

ALL TWO STAGE TYPES ARE FACTORY SET FOR A GIVEN SPECIFIC GRAVITY AND TEMPERATURE FOR EACH APPLICATION

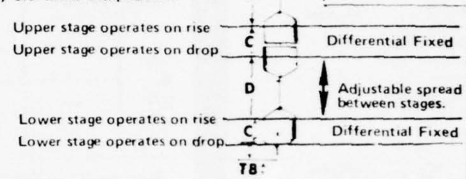
Specific gravity should not vary more than ± .1 from factory setting. Temperature should not vary more than ± 50 F. from factory setting. Note: *Single stage displacer controls will tolerate much wider fluctuations* of specific graviry and temperature as indicated in tables.

WHEN ORDERING - Specify Type No., Circuit Suffix No., Specific Gravity, Pressure & Temperature limitation and insertion Depth(s).

TWO STAGE OPERATION

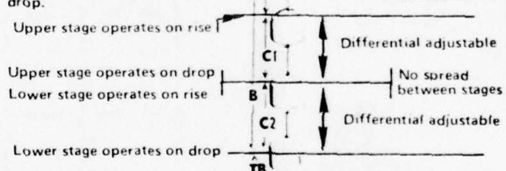
Series 195-4. *Two-Stage-Fixed* Differentials. Adjustable spread *between stages. Min. Specific* Gravity 0.8. Max. Temp. 200°.

	Min.	Max.
A	9"	119"
C	3/4"	Fixed
D	3-1/2"	113-1/2"
TB	1-1/2"	—



Series 195-6. Adjustable *Differential each stage. Lower* stage operates on rise at same *point upper stage operates on* drop.

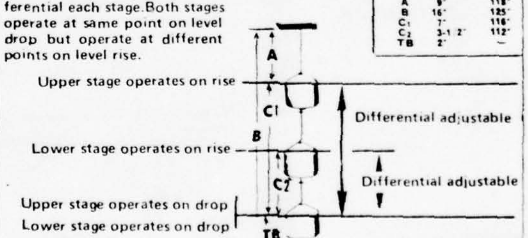
	Min.	Max.
A	9"	118"
B	15-1/2"	125"
C_1	3-1/2"	113"
C_2	3-1/2"	113"
TB	2"	—



Min. Sp.Grav. 0.5 Max.Temp. 200°F.

Series 195-7. Adjustable *Differential each stage.Both stages operate at same point on level drop but operate at different* points on level rise.

	Min.	Max.
A	9"	118"
B	16"	125"
C_1	7"	116"
C_2	3-1/2"	112"
TB	2"	—



Min.Sp.Grav. 0.5; Max. Temp. 200°F.

CIRCUITS AND ELECTRICAL RATINGS

SWITCH TYPE	SWITCH ACTION	Elec. rating Code	SINGLE STAGE	TWO-STAGE LOWER	TWO-STAGE UPPER
Mercury Switch Contacts	SP ST *OPEN* On Level DROP	A	-4821	-4820	-21
	SP ST *OPEN* On Level RISE	A	-4820	-4821	-20
	SP DT ONE SWITCH	B	4810	4810	-10
	SP DT Two Switches Electrically Separate	A	4815	-4815	-15
	DP ST Two Switches *Open on Drop* Electrically Separate	A	-4813	-4814	-13
	DP ST Two Switches *Open on Rise* Electrically Separate	A	4814	4813	-14
	DP DT	B	-4806	-4806	-06
Snap-Action Contacts	SP DT One Switch One *Opens* as other *Closes*	H	-7810	-7810	-10
	DP DT Two Switches	H	-7806	-7806	-06

ELECTRICAL RATING – CAPACITY (AMPERES)

CODE	A–C 120V	A–C 240V	A–C 440V	D–C 125V	D–C 250V
A	10A	5A	3 (1)	10A	5A
B	4A	2A	1 (1)	4A	2A
H	12A	10A	5 (1)	0.5A	0.25A

(1) Available on special order

6135RM

6035EM

6035RM

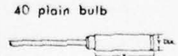
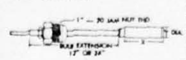
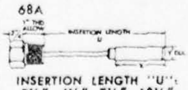
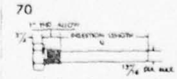
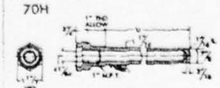
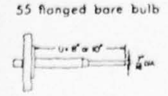
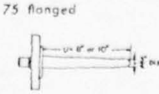
6055RM

Maxivision dial

In 4½" and 6" sizes. Two level dial design, with graduations and pointer on the same plane, eliminates parallax reading errors.

mercury filled thermometers

dial size	figure number	conn.	case: material & type	case: mounting	case: cover	case: dial	case: pointer	case: movement
distant reading								
4½ 6 8½	** 61...RM	lower	phenol turret black other cases*	remote, wall or flush w/1278 ring	plate glass	4½-6 anti-parallax maxivision 8½ conventional		
	** 64...RM	back						
"Every Angle" — direct reading							balanced adjust. black	
4½	** 60...EM	adjust.	stain. steel	direct	glass dome	anti-parallax maxivision		
"Any Angle" — direct reading								
6	** 60...RM	adjust.	phenol or iron					stain. steel
superheater — distant reading								
4½ 6 8½	** 61...RM	lower	gray phenol turret	remote, wall or flush w/1278 ring	plate glass	conventional yellow with black numerals and red set hand	adjust. micro. black	
	** 64...RM	back						
superheater "Any Angle" — direct reading								
6	** 60...RM	adjust.	gray phenol with threaded ring	direct		conventional white with black numerals and red set hand		

bulbs	bushings	wells: standard	wells: heavy duty — solid bored
40 plain bulb 		—	—
35 jam nut  47 flexible extension 	68A  INSERTION LENGTH "U": 2½", 4½", 7½", 10½" 80A  INSERTION LENGTH "U": 2½", 4½", 7½"	without lagging extension 70  with lagging extension 71 	70H  71H 
55 flanged bare bulb 	LAGGING EXTENSION "T": 2" 3" 3" — 3/4" NPT is standard: 1" NPT furnished on request at no extra charge.	75 flanged 	—

RESISTANCE BULBS

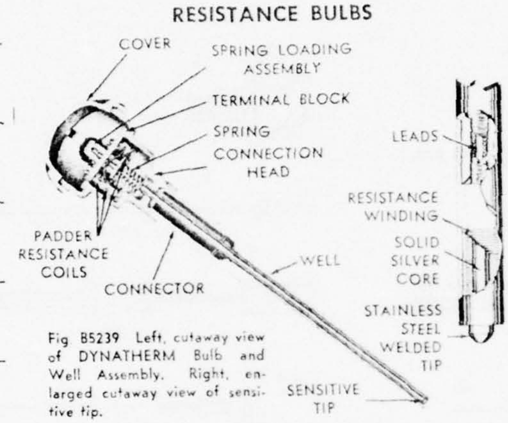


Fig B5239 Left, cutaway view of DYNATHERM Bulb and Well Assembly. Right, enlarged cutaway view of sensitive tip.

A

Fig. B5240

B

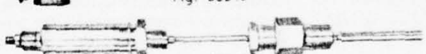



Fig. B5241

C

Fig. B5242

D

Fig. B5243

E

Fig. B5244

F

Fig. B5245

G

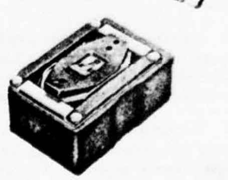



Fig. B5246

H

Fig. B5247

I

Fig. B5482

J

Fig. B5483

Most accurate of temperature measuring systems for temperature ranges from −100 F to +600 F. System consists of DYNATHERM or other nickel-wound resistance bulb connected by standard 3-conductor cable to DYNALOG resistance-type receiver located up to several hundred feet from the point of measurement (see pages A14–A22). Changes in temperature produce changes in resistance which are measured by a Wheatstone bridge circuit in the DYNALOG instrument. Amplified unbalance signal actuates DYNAPOISE drive unit to rebalance bridge and simultaneously position pen, pointer, transmitter unit, control device or other instrument component, uniformly with temperature. Can also be used with Foxboro ERB Series Recorders (see pages A23, A24). For conversion of resistance measurement to 10-50 ma, d-c signal, see Model 694A Converter, next page.

Bulb can be installed bare for faster response required in many processes; or in well—of 1/4-inch nominal size or larger—for added protection against agitation, erosion, corrosion, and pressures in excess of 1000 psi, and for convenient bulb removal without interruption of process. Wells are available in steel, stainless steel, and other corrosion-resistant alloys in any length over 3-1/2 inches, see ACCESSORIES, page D4.

Special bulb assemblies for practically any application may be made from standard parts available from The Foxboro Company.

EXCLUSIVE DYNATHERM BULB FEATURES *Bare bulb application virtually unlimited* through all-stainless-steel, welded-tip bulb construction. Withstands pressures up to 1000 psi. Three times faster in response than well-mounted bulb. *Accuracy and interchangeability* are assured by use of precision-wound padder resistors isolated from heat-sensitive portion of bulb. *Spring-loaded, tip-sensitive construction* provides sustained tip-to-well contact, fastest response, maximum heat transfer, when bulb is mounted in well; *stainless steel protective tube* guarantees dependable bulb performance, even under severe conditions—*tube is bendable*, on minimum radius of 2 inches, for installation in difficult-to-reach locations; *small size bulb*, only 1/4-inch in diameter; available in insertion lengths from 3 inches to 10 feet or more; sensitive portion is only 1-5/8 inches long.

Temperature difference Pen or output changes are equal for any given temperature difference change—whether at 100 F or 500 F. Hence, ideal for Btu calculator, for example.

A DYNATHERM Bulb with Well DB-13N assembly. Die-cast aluminum, weatherproof head; screw-cap with "O"-ring seal; cadmium-plated iron connector, standard well.

B DYNATHERM Bulb with Well DB-23S with well. 316 stainless steel, corrosion- and waterproof head; welded construction with sealed-in cable, standard well.

C DYNATHERM Bulb, Bare DB-21B. Waterproof, entire head and bulb is 316 stainless steel, all-welded construction, non-removable head. Can be furnished with adjustable bushings or with any-pipe-size bushing welded to the extension tubing.

THERMOCOUPLES

A

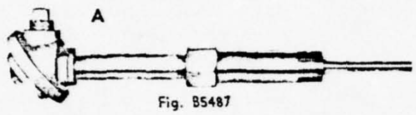


Fig. B5487

B

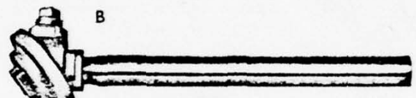


Fig. B5488

C

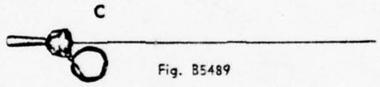


Fig. B5489

D

Fig. B5490

E

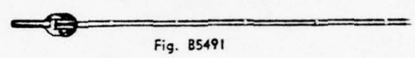


Fig. B5491

F

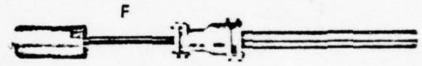


Fig. B5492

G

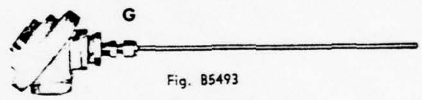


Fig. B5493

Provide widest range of temperature measurement of any measuring system—from as low as −325 to as high as +2800 F—higher than can be measured by either filled thermal or resistance bulb systems. May be wire type, with both elements in wire form; or PYOD type, with one element a closed tube, the other a wire welded to the inside bottom of the tube; or MINOX small-mass type with wire elements magnesium-oxide-insulated in a swaged small-diameter protective sheath. PYOD couples can be used bare on many applications where wire-type couples require protection tubes. Tubes are available for both, however, for protection against extreme temperatures, physical damage, and contamination. Thermocouples are available in the following materials:

Copper-Constantan *Used for continuous service in measuring temperatures to 600 F; intermittent service to 700 F. Available as wire type, or as 1/8-inch OD midget PYOD, or as MINOX small-mass type.*

Iron-Constantan *Wire type used for continuous service in measuring temperatures up to 1550 F and for intermittent service up to 1750 F. PYOD types available with 9/16-inch OD, 1/4-inch OD (baby PYOD), 1/8-inch OD (midget PYOD). MINOX small-mass thermocouples are also available. Applications include liquids and molten metals.*

Chromel-Alumel *Wire or MINOX small-mass types. Used for temperatures above the range of iron-constantan thermocouples. For continuous service up to 2200 F and intermittent service to 2300 F.*

Platinum Rhodium-Platinum *Wire and MINOX small-mass types. Used for temperatures up to 2800 F. Wire type furnished with FLINTEX porcelain protection tube.*

QUALITY CONSTRUCTION, WIDEST VARIETY Thermocouples are manufactured from selected and tested materials and matched to several Foxboro standard calibration curves based on a reference temperature of 75 F and conforming to those generally listed in industry. Couples and accessories, including wells, protection tubes, and extension wires, are available in widest variety of sizes and materials to suit virtually any application, see *Accessories*—page D5.

A Wire Type Couple, with steel well and universal weatherproof head. Connections—3/4 NPT—may be made with either rigid or flexible conduit. For tanks or pipes.

B Wire Type Couple with protection tube and universal connection head. Angle-type assemblies also available.

C Portable Couple of the Foxboro PYOD type. Constructed of an iron tube positive element—sheathing a constantan core negative element. Provides maximum strength and durability. Emf-producing junction is fully enclosed, safe from oxidation or contamination; insures exceptional accuracy.

D Platinum Couple with FLINTEX porcelain protection tube.

E Portable Chromel-Alumel Couple for use in molten aluminum. Wires are not joined at the hot end; junction is made by the molten metal. Portable assemblies are available for all types of couples.

F Standard PYOD Couple, with protection tube, stuffing box, and connection head for installation indoors on furnaces, ovens or ducts. Supplied with weatherproof head, if desired.

G MINOX Thermocouples Small diameter elements—as small as 1/16-inch OD—for use where space is limited. Small mass results in fast response to temperature change. Metal sheath and magnesium oxide insulation assure complete protection of element wires.

AC OR DC SWITCHING APPLICATIONS

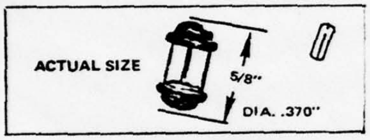
MERCURY CONTACT SWITCHES

HERMETICALLY SEALED

PROVIDES VISIBILITY OF CONTACT ELEMENTS · UNAFFECTED BY DUST, DIRT, LINT, GREASE, ATMOSPHERIC CONDITIONS (HUMIDITY, CORROSIVE OR HAZARDOUS FUMES)

TILTING TYPE

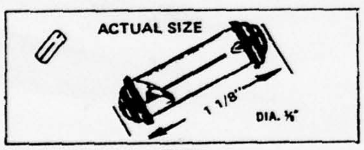
SINGLE POLE – SINGLE THROW



0.6 ampere 120 volts
1.25 amperes 24 volts
Differential angle 20°
Tilt Action - Slow

SWITCH NO. 6-47
WITH METAL-END CAPS

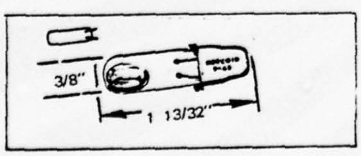
One electrode is attached to each metal cap with a small gap between them at one end of the tube and when the tube is tilted in that direction, the mercury flows and bridges the gap to close a circuit. When tilted in the opposite direction, the mercury flows away to restore the gap and open the circuit. Spring clips or holders are used for mounting purposes.



SP-ST
1.75 amperes 120 volts
0.6 ampere 240 volts
Differential angle 8°
Tilt Action - Fast or Slow

SWITCH NO. 6-65

Same as No. 6-47 described above except with higher electrical capacity.

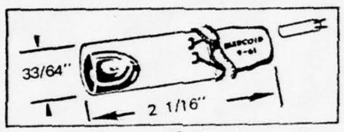


SP-ST
1 amperes 120 volts
0.5 ampere 240 volts
Differential angle 10°
Tilt Action - Fast or Slow
Use Clip No. 7-151

SWITCH NO. 9-65

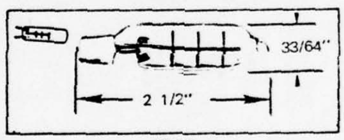
TILTING TYPE

SINGLE POLE – SINGLE THROW



SP-ST
4 amperes 120 volts
2 amperes 240 volts
1 amperes 440 volts AC
Non-Inductive rating
9A. 120V., 4½A. 240V.
Differential Angle 5°
Tilt Action - Fast or Slow
Use Clip No. 7-57

SWITCH NO. 9-61



SP-ST
4 amperes 120 volts
2 amperes 240 volts
1 ampere 440 volts AC
Differential Angle 5°
Tilt Action - Fast or Slow
Use Clip No. 7-57

SWITCH NO. 9-35
ANTI-VIBRATION SWITCH

Minimizes false contact under severe high frequency vibrations. (The mils shown in the following values are actually double the amplitude 60 mils means 30 mils in each direction).

Cyles Per Second	Vibration (Mils .001") Vertical	Horizontal
120	30	25
60	45	55
30	72	100

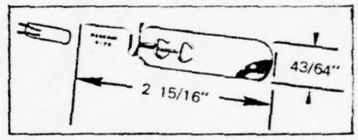
4 amperes 120 volts
2 amperes 240 volts
1 ampere 440 volts AC
Differential Angle 5°
Tilt Action - Fast or Slow
Use Clip No. 7-57
SWITCH NO. 9-43

MOMENTARY CONTACT

Electrodes are located in the center of the tube, hence, each time the tube is tilted, the mercury flows past the electrodes to provide a momentary "pulse".

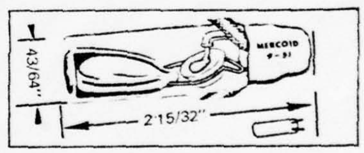
TILTING TYPE

SINGLE POLE - SINGLE THROW



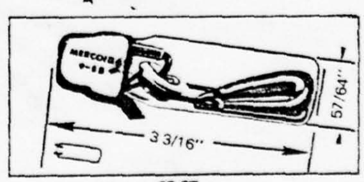
SP-ST
6 amperes 120 volts
3 amperes 240 volts
1 ampere 440 volts AC
Differential Angle 2½°
Tilt Action – Slow
Use Clip No. 7-39

SWITCH NO. 9-78



SP-ST
10 amperes 120 volts
5 amperes 240 volts
3 amperes 440 volts AC
Non-Inductive Rating
17A. 120V/240V. AC.
Differential Angle 8°
Tilt Action - Fast or Slow
Use Clip No. 7-59

SWITCH NO. 9-51



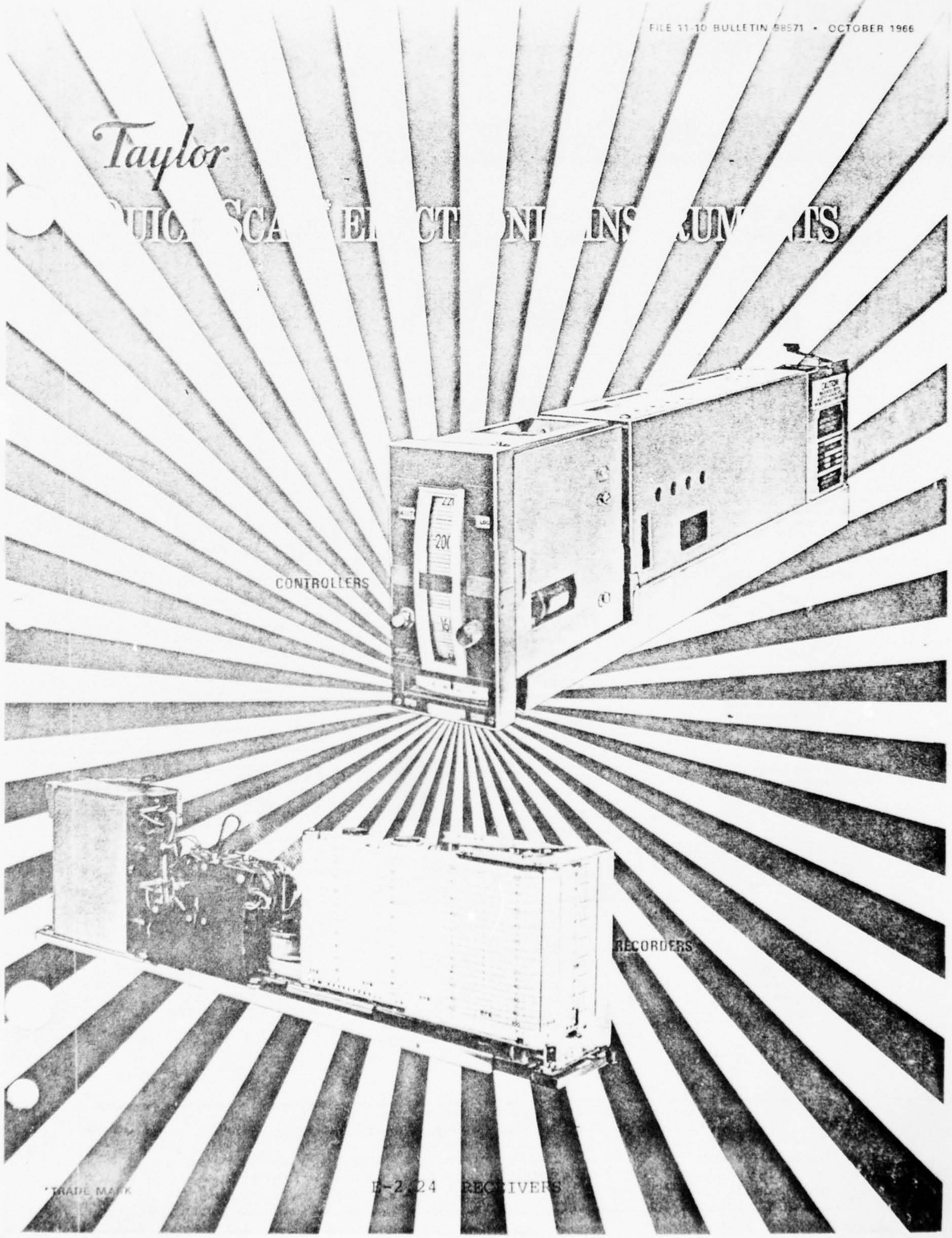
SP-ST
25 amperes 120 volts
15½ amperes 240 volts
6 amperes 440 volts AC
Non-Inductive rating with
Type SF leads (page 4)
25 amperes 120 volts 2875 watts
25 amperes 240 volts 5000 watts
Use Clip No. 7-191
SWITCH NO. 9-55

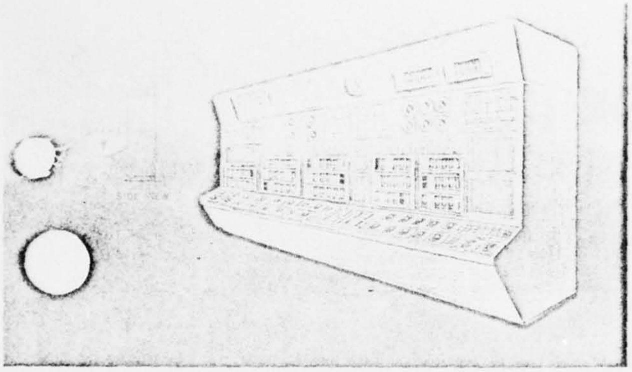
HEAVY DUTY SWITCH

ALL TYPES AVAILABLE WITH OR WITHOUT LEADS - SEE PAGE 60.
MOUNTING CLIPS - SEE PAGE 60. ENCAPSULATION - SEE PAGE 60.

MERCOID CONTROL

Mercoid Hermetically Sealed Mercury Switches are backed by over fifty years of engineering know-how. The switches shown in this bulletin are standard items and can be varied to accomodate any need - such as longer tube lengths, changes in electrodes and with special lead construction.


FILE 11-10 BULLETIN 98571 • OCTOBER 1966
Taylor
QUICK SCAN ELECTRONIC INSTRUMENTS
CONTROLLERS
RECORDERS
*TRADE MARK
B-2.24 RECEIVERS



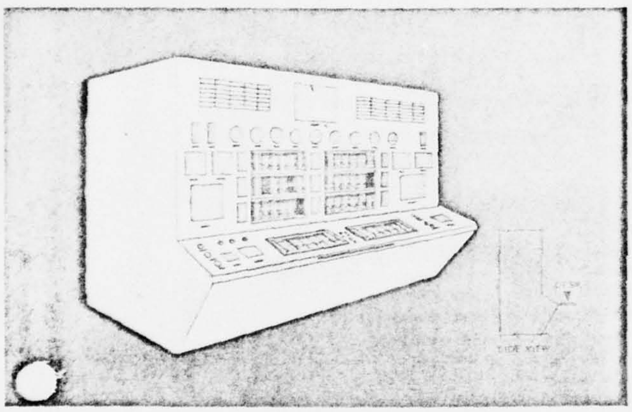
Taylor

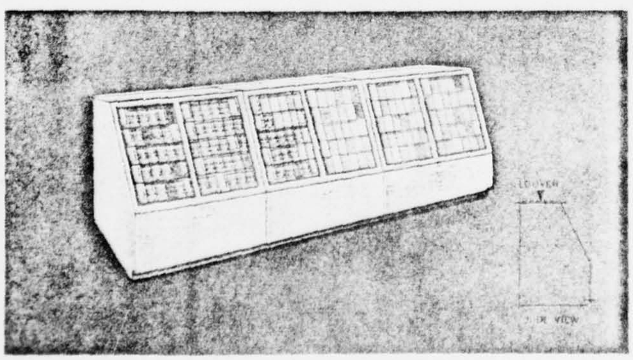
ELECTRONIC PROCESS CONTROL SYSTEMS

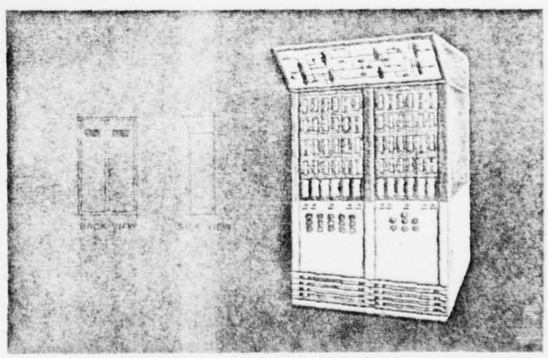
for advanced control room concepts

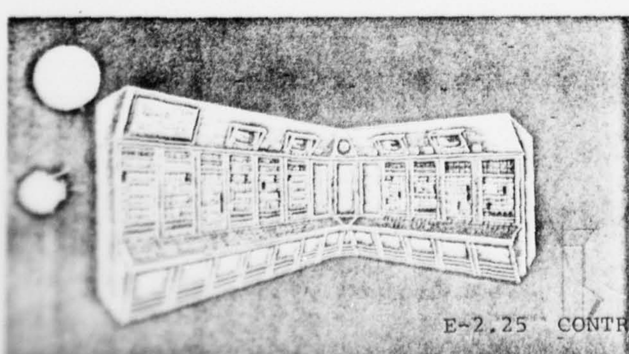
for compatibility with computer systems

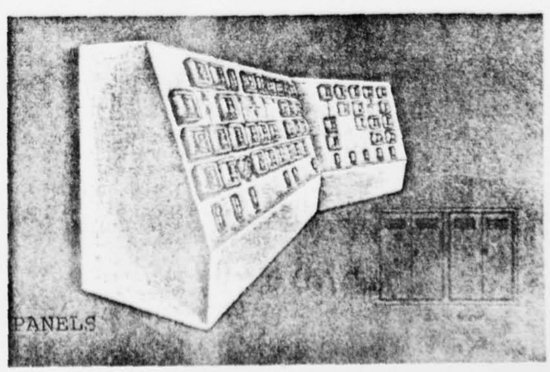
for a complete line of field instrumentation and accessories







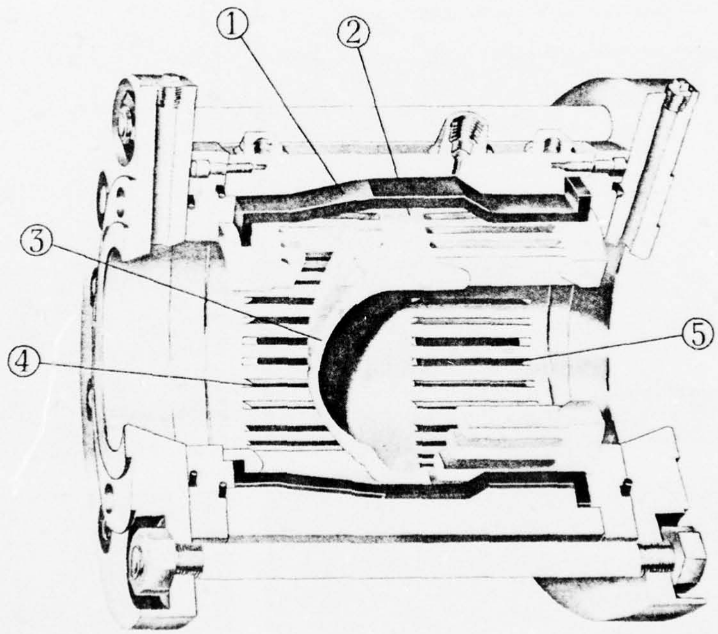




E-2.25 CONTROL PANELS

only one moving part for trouble-free performance

The flexible GROVEX tube (1) is the only moving part in the Grove Flexflo. Silent flexing action of *the tube over a core (2)* is controlled by the pressure in the jacket space (the area between the tube and the body). The Flexflo can never slam, stick, or wedge. The core barrier (3) directs the incoming fluids up through the inlet slots (4) *expanding the tube* and down through the outlet slots (5). The flexible tube assures positive shutoff even though foreign matter may be trapped between the core and tube.



flexflo® performance features

• Quiet Operation . . . The only moving part in the Flexflo is the expansible tube. Aggravating regulator noise problems are solved by installing Flexflos.

• *Tight Shutoff . . . Positive shutoff* is assured even with comparatively large particles in the flow stream. The expansible tube conforms to the core contour despite operational wear.

• Infinite Rangeability . . . The Flexflo features a core design that increases the flow range and eliminates the need for an expensive inner valve. *The Flexflo can be sized to* meet future loads and be used today without cycling. The core has a seating surface with a 5° slope toward the outlet slots, creating a long narrow orifice between the tube and core. Throttling action is much like a long taper needle valve in contrast to a needle point valve.

• Compact . . . Minimum overall size is inherent with the Flexflo's simple clean design. In many applications, regulator station capacity has been increased without enlarging the station, by replacing massive, bulky conventional regulators with compact Flexflos. Large and expensive "formed and poured" concrete vaults are not required with Flexflos — savings up to 50% are possible with compact, pre-cast vaults.

• Adaptable . . . Because of its unique design, the basic Flexflo is adaptable with only a change of pilots to pressure reducing, back pressure, relief, and automatic shutoff service, as well as motor valve operation — reduce inventory stocks.

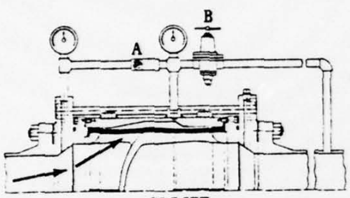
• Dependable . . . The Flexflo is ideally suited for emergency or infrequent operation. The expansible tube gives tight shut-in during long periods of inaction and quick opening on demand. Unlike conventional valves, there are no metal-to-metal seals or stem packing. Leakage and valve sticking are eliminated.

• *Ease of Inspection* . . . Bolted construction design for ease of inline inspection.

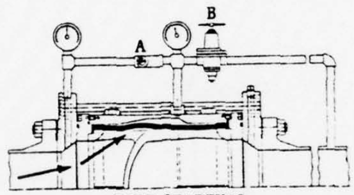
how the flexflo® operates

Pressure differential controls tube travel. The fixed metering orifice "A" and variable orifice pressure regulator "B" control tube differential.

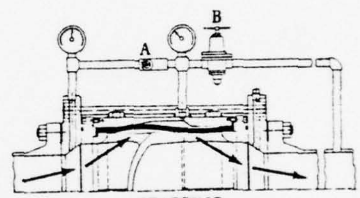
Pressure is controlled smoothly and accurately. Shutoff is positive. When the pressure reduction is critical, wide open flow occurs when the pressure on top of tube is reduced to one-half inlet pressure. When pressure reduction is sub-critical, pressure on top of tube must be reduced to outlet pressure for wide open flow.



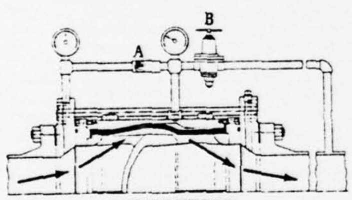
CLOSED
Inlet pressure is equalized on top of tube.



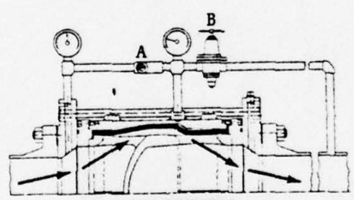
TUBE STARTING TO LIFT



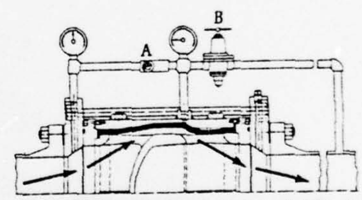
STARTING TO THROTTLE



THROTTLING



THROTTLING

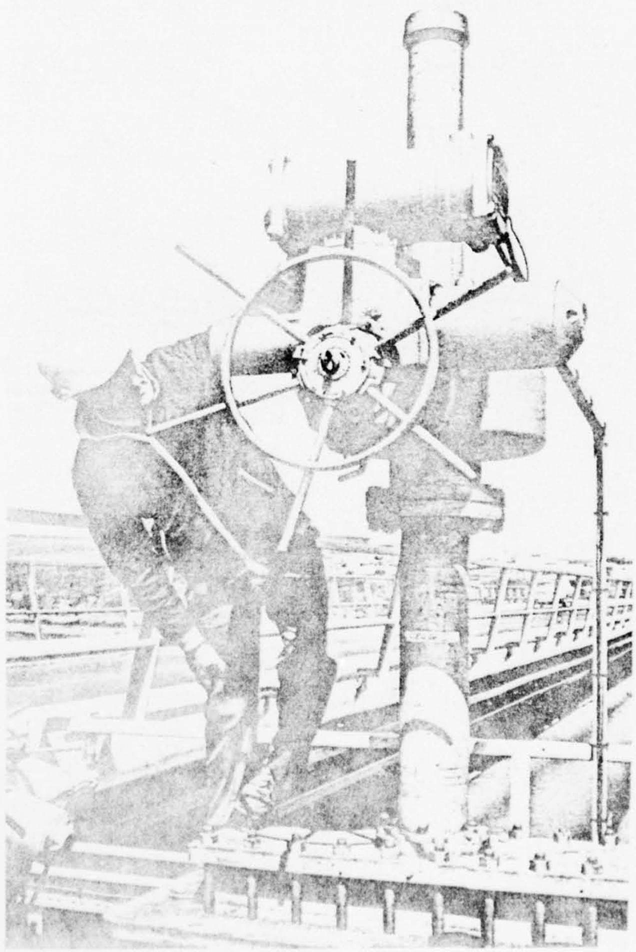


WIDE OPEN — Pressure on top of tube is equal to downstream pressure, or one-half inlet pressure (see above).

rotork

Catalog section 4
Publication number AE4/O
Date of issue 3/77

Valve Actuator electrical specifications. Syncropak 1400 series and Syncroset.



Rotork A-Range electric actuators with their O-ring sealed enclosures have established an enviable reputation worldwide for reliable operation of motorized valves. The advantages of the Syncropak design with integral control package have become very apparent – reduced costs of hardware, building, cabling and installation, with simplified engineering, procurement and field start-up.

During recent years the increased use of Syncropak actuators in automatic sequencing, supervisory and computer control systems has given rise to a number of additional requirements, dealt with by special wiring diagrams. As a result of this experience, the specification of Rotork Syncropak is now further advanced by the introduction of the new 1400-series of wiring diagrams which supersede the present 1200-series (1210-40 to 1211-53). 1400-series Syncropak not only covers all the basic control requirements as hitherto but also readily provides for the most sophisticated supervisory and sequencing requirements. Use of these standard diagrams brings all the added advantages of ready availability and assured reliability from established quality control procedures on proven products.

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telephone (716) 328-1550
telex 978-290
cables Rotork Rochester

Rotork Controls of Canada Limited
55 Brisbane Road
Downsview, Ontario
M3J 2K3
telephone (416) 661-1200
telex 06-217760

Rotork Controls Limited
Bath BA1 3JQ, England
telephone (0225) 28451
telex 44823
cables Rotork Bath

PRODUCT FEATURES

- NO GEARING . . . provides full, direct power to valve stem
- AUTOMATIC . . . adaptable to any type of remote control signal
- EASY INSTALLATION . . . can be fitted to any valve, at any location
- LOWER MAINTENANCE/OPERATING COSTS . . . only one moving part
- EASILY CONTROLLED OPERATING SPEED . . . uses optional hydraulic orifice
- VALVE PROTECTED FROM OVERLOAD DAMAGE . . . uses optional adjustable relief valve
- EMERGENCY OPERATION . . . manual pump on all units operates actuator during power failure
- NO SIDE THRUST ON VALVE STEM . . . operator is mounted directly over valve
- "BALANCED TORQUE" achieved by Shafer's double vane design

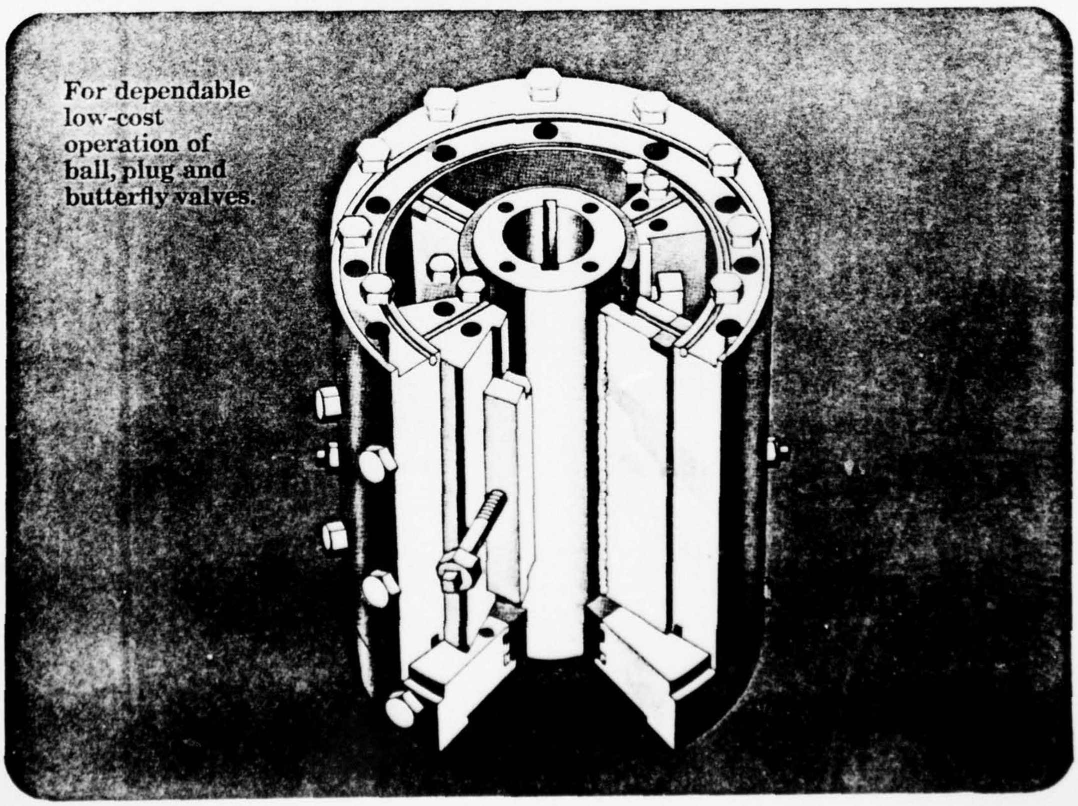
CONSTRUCTION

• Simple, basic design with only one moving part, no power-absorbing gearing • Double-vane, balanced torque design • Fabricated from high quality steel plate, ground to precision tolerances • Composition seals for leakproof operation at high pressure • Bronze plates on rotor vanes, bronze bushings on heads provide low friction bearing surfaces • Rotor stops (externally adjustable) limit rotor travel for specific valve applications • Bottom head and rotor bore machined to match top works and stem of any valve

BULLETIN RV–120

Shafer

ROTARY VANE VALVE OPERATORS



PRINCIPAL OF OPERATION

SEQUENCE 1

The operator may be powered by line pressure, stored gas pressure, or by a central hydraulic system. In this diagram the operator is fitted with gas hydraulic tanks and will be powered by line pressure. However, at this time, the operator is in the open position and there is no pressure in the operator or tanks.

SEQUENCE 2

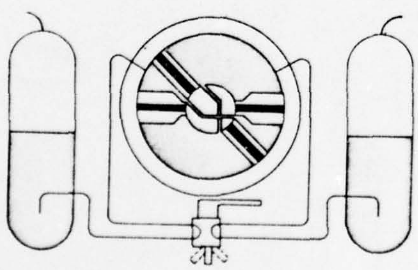
When the control is actuated, line pressure is admitted to the closing gas hydraulic tank and forces pressurized hydraulic fluid through the hand pump and into the operator's closing port. Pressure equalizing passages allow both closing quadrants to be pressurized providing balanced torque in pushing the vanes away from the stationary shoes. As the rotor and vanes rotate clockwise (to close position), the oil in the remaining quadrants, also connected by a pressure equalizing passage, is pushed out of the operator's opening port.-through the hand pump and into the opening gas hydraulic tank. Back pressure in the opening tank is allowed to vent to atmosphere via the control exhaust port.

SEQUENCE 3

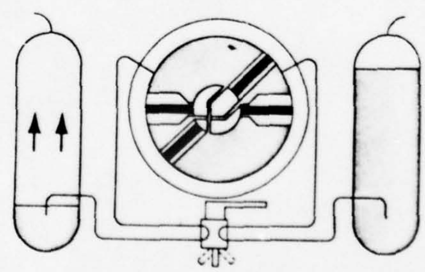
When the operator reaches the fully closed position, the control will neutralize and allow all remaining line pressure to vent to atmosphere, thus neutralizing tank and operator pressure.

OPTIONAL LEVELING CHECK VALVE

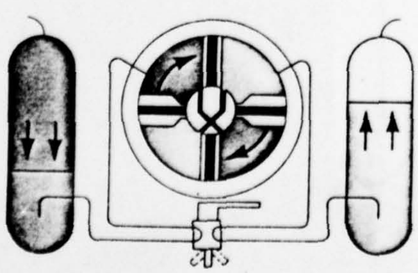
For operators used in a rapid cycling application, and as a customer option, a leveling check or shuttle valve is installed between the tanks. During normal operation the tanks are locked apart, but during neutralization a spring centered shuttle valve allows rapid equalization of oil levels.



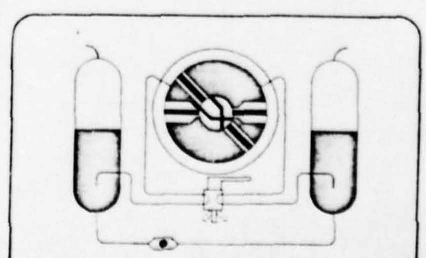
SEQUENCE 1 VALVE FULLY OPEN



SEQUENCE 3 VALVE FULLY CLOSED



SEQUENCE 2 VALVE CLOSING



OPTIONAL LEVELING CHECK VALVE

PRODUCT FEATURES

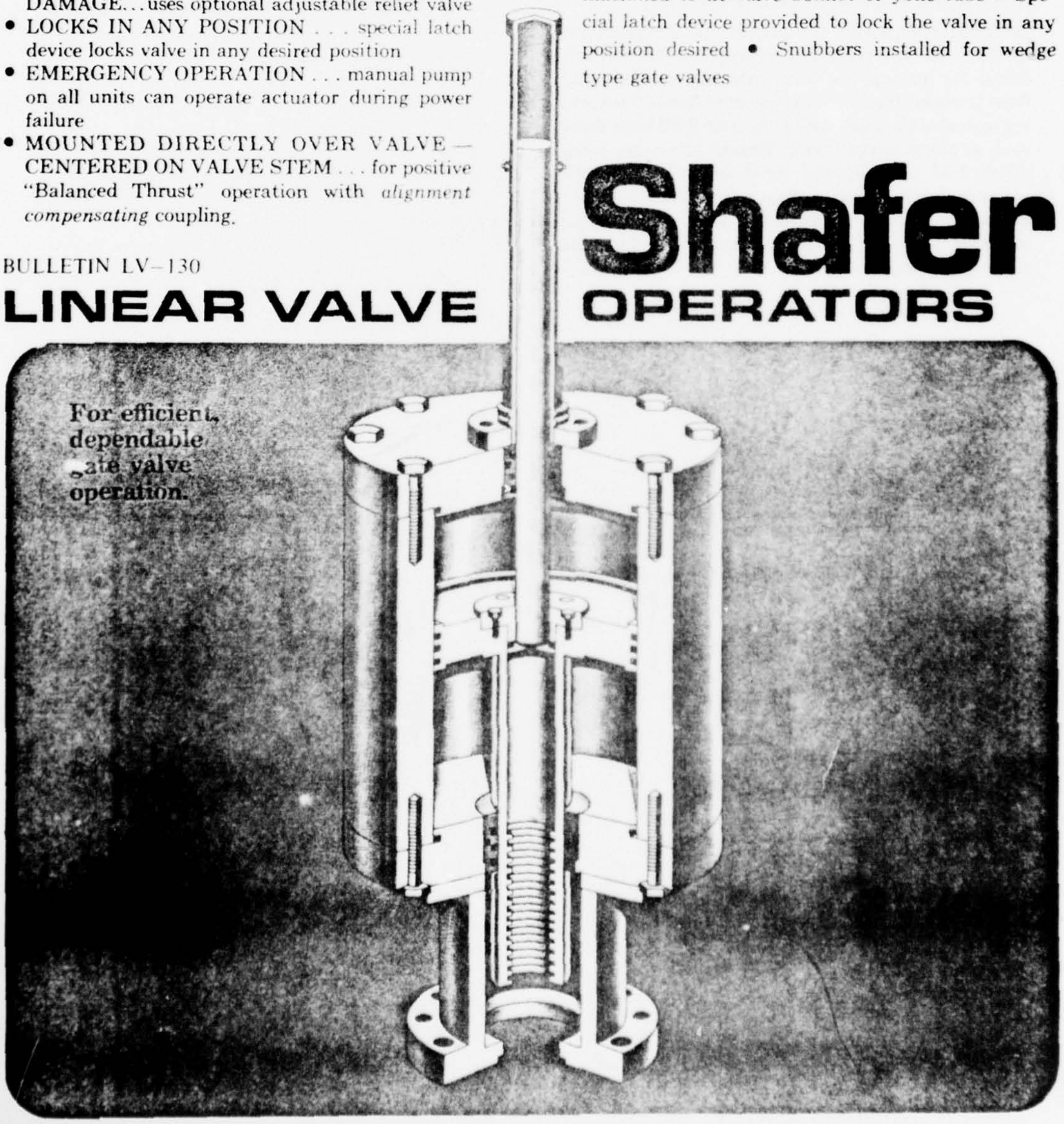
- NO GEARING . . . provides full, direct power to valve stem
- AUTOMATIC . . . adaptable to any type of remote control signal
- EASY INSTALLATION . . . can be fitted to any valve at any location
- LOWER MAINTENANCE/OPERATING COSTS . . . only one moving part
- EASILY CONTROLLED OPERATING SPEED . . . uses optional hydraulic orifice
- VALVE PROTECTED FROM OVERLOAD DAMAGE. . . uses optional adjustable relief valve
- LOCKS IN ANY POSITION . . . special latch device locks valve in any desired position
- EMERGENCY OPERATION . . . manual pump on all units can operate actuator during power failure
- MOUNTED DIRECTLY OVER VALVE — CENTERED ON VALVE STEM . . . for positive "Balanced Thrust" operation with *alignment compensating* coupling.

CONSTRUCTION

• Simple, basic design with no power-absorbing gearing. Hydraulic piston principle provides fast, smooth operation—without shock • Made from high quality steel plate, ground to precision tolerances • Composition seals and fibre wipers assure leakproof operation at high pressure • Low friction bearing surfaces are provided by a bronze coating on the piston diameter and bronze bushings in the heads • Piston is threaded to valve stem • Mounting bracket machined to fit valve bonnet or yoke tube • Special latch device provided to lock the valve in any position desired • Snubbers installed for wedge type gate valves

BULLETIN LV–130

LINEAR VALVE Shafer OPERATORS



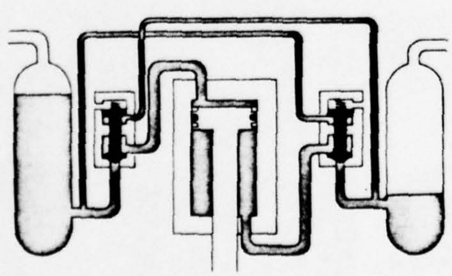
PRINCIPAL OF OPERATION

Full brute power . . . without the slightest suggestion of shock. That's the story behind precision-built, quick-response linear valve operators by Shafer. Hydraulic pressure is applied directly to the valve stem through the piston. There are no in-between gears to rob the operator of its initially developed power or to slow down valve response. Operation is fast, positive and fully reliable every time.

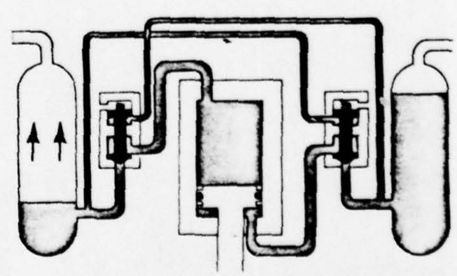
Designed specifically for gate valve installations, Shafer linear operators feature a special double latch device for locking the valve into any desired position. It works like this: Gas pressure forces fluid into the operator through one latch. The fluid then flows back to the receiving tank through the other latch which had been opened previously by hydraulic pressure forcing the poppet away from the seat. When the pressure is removed, both latches close, retaining the fluid in the operator and locking the valve firmly in position.

PERFORMANCE CHARACTERISTICS

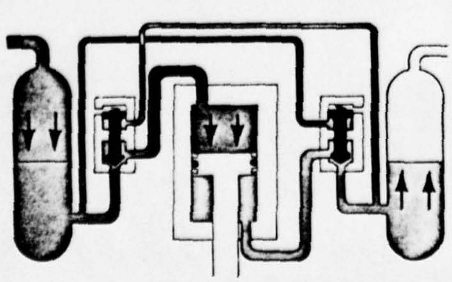
• Operated remotely or automatically by a variety of sensory and control devices • Can be furnished with a wide variety of high or low pressure pilot control mechanisms for almost any safety or other operation requirement • Actuator system will automatically close valves when a line break occurs, blow down an entire station if fire danger is imminent or function in complex storage and distribution systems



VALVE FULLY OPEN

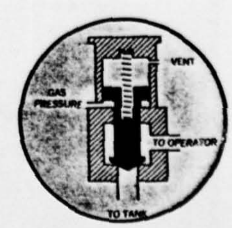


VALVE FULLY CLOSED



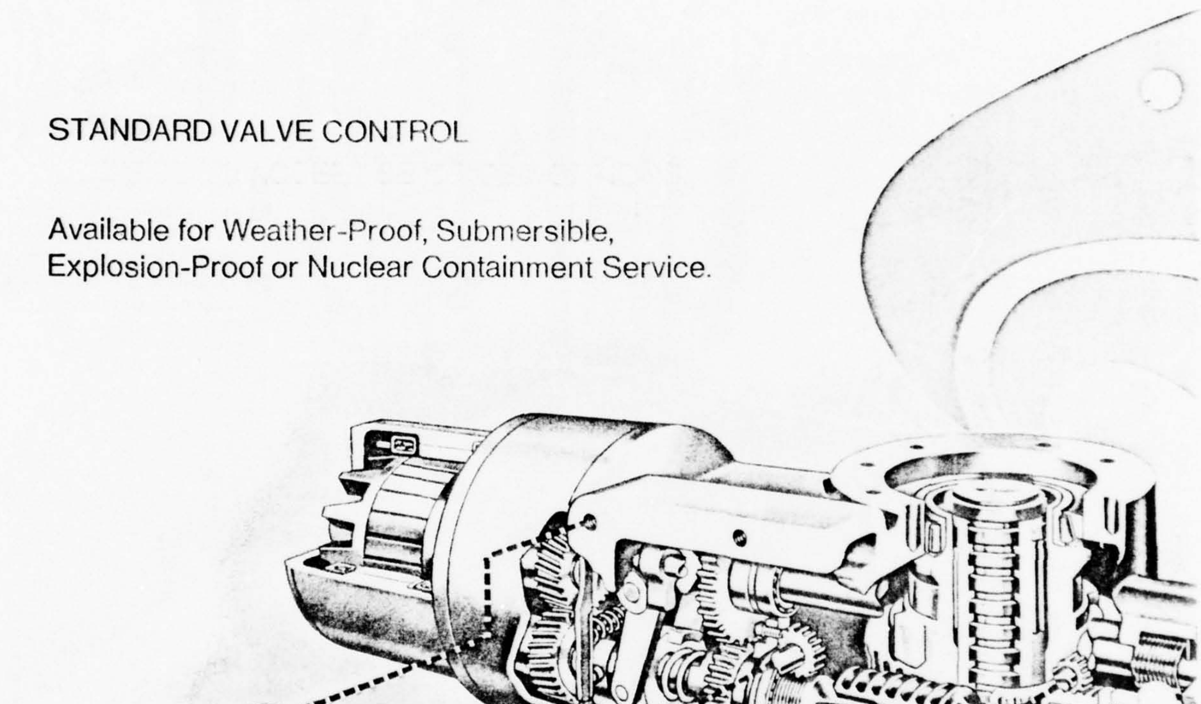
VALVE CLOSING

LOCK IN ANY POSITION
Shafer Lineal Operator Systems feature special latch devices to lock gate valves in any desired position.



STANDARD VALVE CONTROL

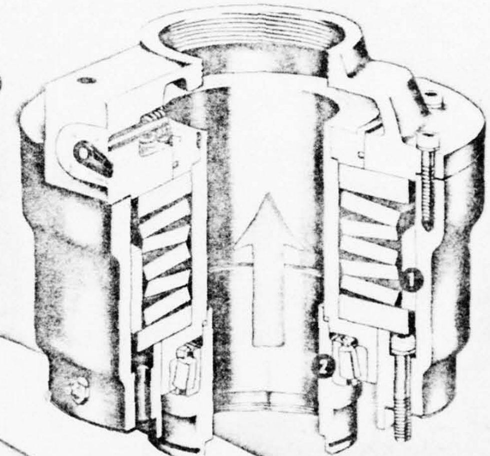
Available for Weather-Proof, Submersible, Explosion-Proof or Nuclear Containment Service.

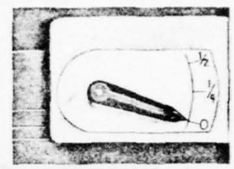


Full Range of
Limitorque Electrical Control Options

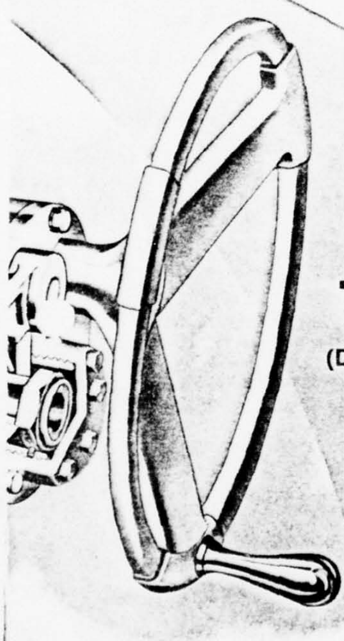
Type SB

(Single Compensating)



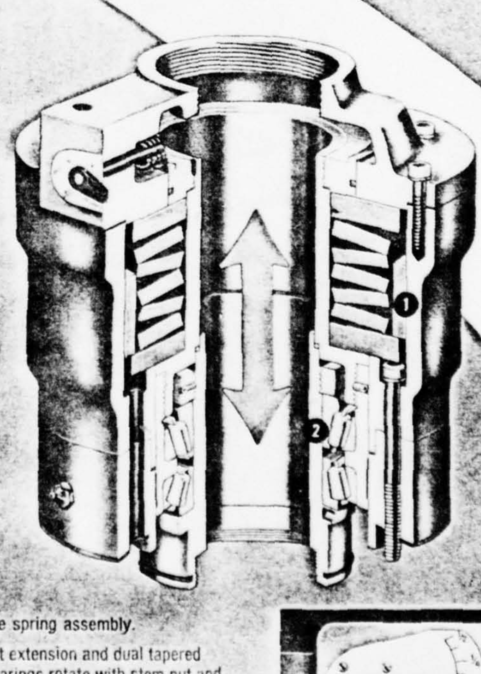


1. Belleville spring assembly.
2. Stem nut extension and tapered roller bearing rotate with stem nut and transmit thrust to spring pack.
3. Indicators show amount of spring compression as standard on SB/SBD 0 and larger.

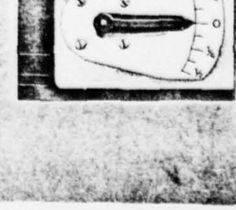


Type SBD

(Double Compensating)



1. Belleville spring assembly.
2. Stem nut extension and dual tapered roller bearings rotate with stem nut and transmit thrust to spring pack.
3. Indicators show amount of spring compression as standard on SB/SBD 0 and larger.



E-3 SPECIFIC COMPONENTS

The following section contains supplemental descriptions of the Equipment Staging Diagrams and Control System Diagrams of Section 2.0, "System Characterizaton". Each of the components listed on the ESD's which make up the various control systems is dealt with individually. A short description and purpose paragraph supplements the more general descriptions given in Section E-1 of this Appendix. The following are also considered for each component:

- Reliability Spill Risk
- Potential Failure Modes
- Effects of Failure
- Alternate Procedures

Standards and Regulations

The criteria for selecting components should follow the established industry standards and Federal regulations listed below. This is not to be considered an exhaustive list since it is limited to normal applications on a Deepwater Port; any specialized or unusual equipment may require other standards or regulations.

Code of Federal Regulations

33 C.F.R. - 149, Subpart C. Pollution Prevention Equipment

33 C.F.R. - 150, Subpart D. Oil Transfer Operations

46 C.F.R. - 111.80, Special Requirements for Certain Locations and Systems

46 C.F.R. - 111.80, Subpart 1. Application

46 C.F.R. - 111.80, Subpart 5. Wiring Methods and Materials for Hazardous Locations

46 C.F.R. - 111.80, Subpart 8. Intrinsically Safe Systems

49 C.F.R. - 195, Transportation of Liquids by Pipelines

Industry Standards

ANSI	B31.4	- Liquid Petroleum Transportation Piping Systems
ANSI	B16.5	- Steel Pipe Flanges and Fittings
API	RP500	- Electrical Installations at Petroleum Facilities
API	RP550	- Manual on Installation of Refinery Instruments and Control Systems, Part I and II
API	2534	- Measurement of Liquid Hydrocarbons by Turbine Meter Systems

Maintenance

The analysis of the data collected and contained in this study has assumed that an adequate maintenance program would be followed. It is important and essential to the smooth operation of any Deepwater Port that it be properly maintained. With regard to the components that make up the control systems described in this report, maintenance, for the most part, would mean replacement of faulty or failed components. A program of preventative maintenance involving periodic inspection of components can go a long way to preventing unnecessary shutdown and interruptions.

11000 <u>DISCHARGE OIL FROM TANKER</u> (Fig. 2-4)

11100 <u>Line Up Tanker Valve System</u> (Fig. 2-5)

The control systems which monitor and control the operation of the valves can be either pneumatic, hydraulic, or electric. The latter appears to be the exception due to the hazardous nature of the cargo and the attendant risk of electrical sparks.

Whether the system is pneumatically or hydraulically actuated is immaterial since the basic principle and equipment are similar. Generally, the opening and closing of the valves is initiated from push buttons and/or levers in the remote control room where all controls and monitors are concentrated on a schematic type control panel or desk.

11101 <u>Valve Line Up Monitor</u>

11101/01 <u>Remote Indicator</u>

<u>Description and Purpose</u> - These panel mounted indicators tell the operator whether a valve is open or closed. They may be an electrically operated light, or a target type, whereby a disc is mechanically moved by a feedback pressure from the valve. In the case of the electric light, an interposing pressure sensitive switch is necessary to convert the pneumatic or hydraulic feedback signal from the valve actuator.

<u>Reliability Spill Risk</u> - The failure of a remote indicator could mislead an operator into believing a valve is closed when it is open or vice versa. Oil would then be routed incorrectly to a full tank or unconnected manifold and result in a spill.

Potential Failure Modes - Failure of a lamp may be fairly frequent but easily detected since most panels have a built in lamp testing feature. Failure of the pressure mechanical type of indicator would be caused by leaks in the hydraulic system.

Effects of Failure - No chain reaction whereby other equipment may be affected is anticipated.

Alternate Procedure - Reference to the local indicators built into the valve actuator will provide the required information.

11101/02 Local Indicator

Description and Purpose - Valve control systems which do not include a feedback system can be visually checked for position. Usually, a rod fitted to the main stem of the valve will indicate this, or if the valve is not of the rising stem type, an indicator on the actuator will give the required information. This information will be communicated to the central control room, usually over radio (walkie talkie).

11102 Valve Line Up Controller

11102/01 Push Button Remote

Description and Purpose - On tankers, this remote control can take the form of an electrical push button operating a hydraulic signal through a solenoid valve, or it can be a lever which directly operates a hydraulic or pneumatic valve. The purpose of these controls is to open or close the valves allowing oil from the various ship's tanks to

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STUDY OF DEEPWATER PORT OIL TRANSFER CONTROL SYSTEMS.(U)
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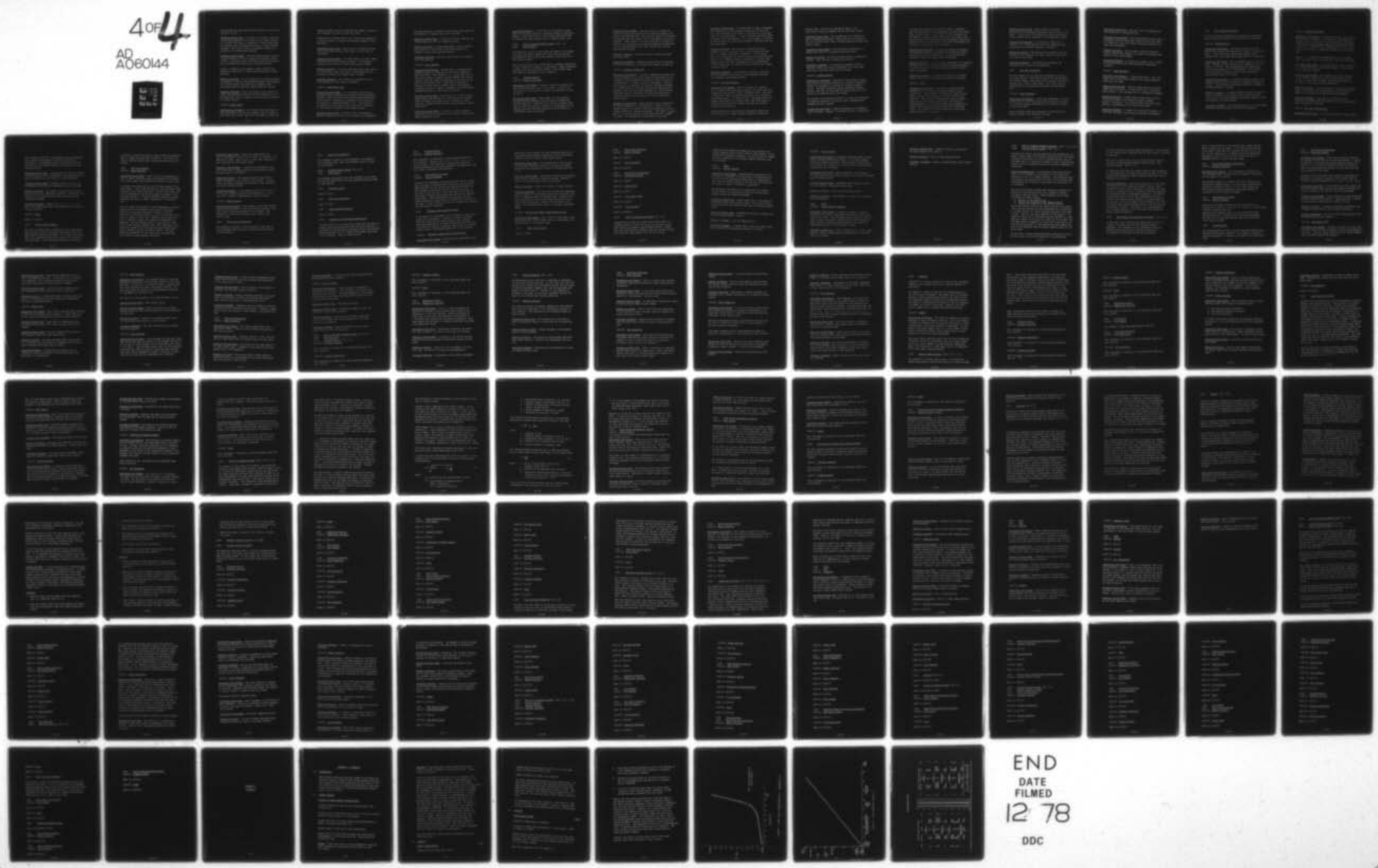

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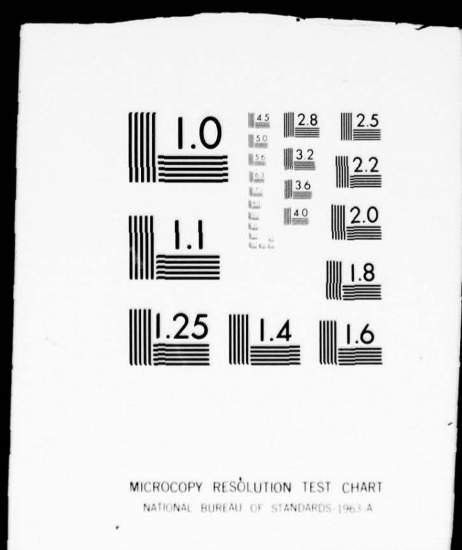


flow through the pump suction and discharge to the ship's manifold on deck.

Reliability Spill Risk - If there is no remote indication of the valve position, the failure of the remote control to initiate the closing or opening of a valve could lead the operator into incorrectly believing a valve has been actuated. The result could be incorrectly routed oil, possibly to an unconnected manifold.

Potential Failure Modes - The most common mode of failure of push buttons is the wire connections becoming disconnected. A secondary type of failure would be the wearing out of mechanically moving parts inside the switch.

Failure of hydraulic or pneumatic valves would be the wearing of seals and "O" rings causing the valve to malfunction.

Effects of Failure - If not resulting in an obvious spill, the effects of failure would become apparent when pressure at the pump suction fell below an acceptable level. A time delay would be the most common effect of failure.

Alternate Procedure - With the failure of the remote controls, the alternative would be for the operator to go to the particular valve in question and initiate the opening or closing locally.

11102/02 Manual Local

Description and Purpose - This item is the hand wheel or lever provided on the valve to manually open or close it. With large-size valves, gearing is provided to reduce the

effort required, but this increases the number of turns of the hand wheel to open or close the valve.

Hydraulically operated valves will require the pumping of a lever in order to provide the required pressure to move the valve.

Reliability Spill Risk - Since this is a mechanical operation which takes place at the valve, no spill risk is considered.

Potential Failure Modes - For hand wheels, the most common failure would be the seizing of gears. For hydraulic actuators, the failure of seals would be most common.

Effects of Failure - Failures described above would result in a time delay, while the cause is determined and the situation corrected and brought back to normal.

Alternate Procedure - No alternative procedure for the local operation of the valve is possible.

11102/03 Push Button Local

Description and Purpose - It is unlikely that electric actuators would be employed on tankers carrying hazardous cargoes so the local push button considered would mechanically actuate a hydraulic or pneumatic valve either on the actuator or mounted adjacent to it. The purpose is to operate the valve from a local position in the event of the failure or absence of any remote control.

Reliability Spill Risk - No spill risk is envisaged on failure, unless the valve is to be closed in an emergency,

then the resorting to manual closing would take longer and the chances of a greater spill are increased.

Potential Failure Modes - Failures would be caused by the leaking seals and worn out mechanical parts.

Effects of Failure - As described above, failures would only result in a time delay, while the situation is remedied or the valve operated manually.

Alternate Procedure - The only alternative is to operate the valve manually.

11102/04 Valve Actuator

Description and Purpose - Hydraulically or pneumatically operated valves are installed on the latest classes of VLCCs and ULCCs. The actuators for rising stem types of gate valves employ a simple cylinder whereby the stem is integral with the piston and pressure on one side or the other will move the valve. Those valves requiring a rotational action have actuators either with opposing cylinders acting on a yoke, or hydraulic vane type motors connected directly to the stem of the valve.

Reliability Spill Risk - The failure of a valve actuator could prevent the closure of a valve and in the unlikely event of nothing else being able to prevent it (pump stopping, closing of other valves in the system), a spill would occur.

Potential Failure Modes - Failure of a valve actuator would most likely be caused by faulty seals or worn parts leaking hydraulic fluid.

Alternate Procedure - If the valve is fitted with a hand wheel, this can be used as an alternate method of operation. However, those fitted with a local manual pump would come up against the same actuator fault of leaking seals, etc.

11200 Move Oil Through Tanker System (Fig. 2-6)

11210 Start Pumping

Following the line up of the valves and tanks on the tanker, the request to start pumping must come from the terminal operators who have lined up the system to route the oil to the onshore storage.

Pump room operators rely a great deal on pressure indicators to tell them how the pump(s) is performing. These indicators, together with the known head (level) in the suction tank, tell them the approximate rate of pumping.

11211 Pressure Monitor

11211/01 Pressure Indicator

Description and Purpose - Pressure gauges are probably the most common instrument used on the tanker. They are an important tool and provide a variety of information to the operators.

Reliability Spill Risk - Most gauges, if not regularly maintained and calibrated, can give false readings and mislead operators. Although not a part of a control loop, they do serve an essential function in the movement of oil through pipelines and their malfunction could result in unnecessary action being taken.

Potential Failure Modes - The usual cause of failure involves the gauge being subjected to pressures greater than those it was designed for. This has the effect of straining the Bourdon Tube and results in the instrument giving false readings. Other causes of failure would be the effects of corrosion on the gearing and constant pressure fluctuations, as on a pump discharge, which will rapidly wear out the internal moving parts.

Effects of Failure - No chain reaction on other controls will take place.

Alternate Procedures - Redundant gauges could be installed at critical locations to increase the overall reliability.

11211/02 Pressure Transmitter

Description and Purpose - Pressure transmitters measure the varying pressures in a piping system and transform it into a signal, either pneumatic or electric, which can then be "transmitted" to a remote receiving instrument. Briefly, the principle of operation is the small movement produced in a sealed capsule or Bourdon Tube by the pressure being measured, this in turn causes movement of a force balance beam which acts on a system of bellows and nozzles for a pneumatic output or on a moving iron for an electrical signal output.

Reliability Spill Risk - False signals can be transmitted by this instrument if it malfunctions. Often it is the measuring part of a control loop and can therefore have an adverse affect on a regulating device. This type of instrument is of a proven design and has been used for a number of years. Its reliability is considered to be good.

Potential Failure Modes - Although most of these instruments are fitted with an over pressure protection device, this will only withstand in the order of 150 percent of the maximum of its design range. Failure therefore could be caused by hammer shocks and surges in the piping system. Corrosion of moving parts will also cause failure if the parts are not well maintained.

Effects of Failure - The pressure transmitter will be either a part of a control loop, or will provide the signal for a remote indicator or recorder. In the former case, the consequences of failure would have a more serious effect - for example, causing a controller to adjust pump speed either up or down, dependent upon the malfunction. In the latter case, an operator could be misled into taking incorrect action.

Alternate Procedure - In the event of failure, the alternative procedure is to manually read pressures and make the necessary adjustments by hand.

11211/03 Pressure Recorder

Description and Purpose - Usually mounted on a central control panel, this instrument receives the signal from the transmitter and records it on a time-base chart. The chart is driven by either a clockwork mechanism, or an electric synchronous motor. Two basic types of recorders are on the market, those having a circular chart, and those having a strip chart which is more compact and does not require frequent chart changing.

The mechanism which received the transmitted signal and drives the pen is a small pressure sensitive bellows or

helical wound tube for the pneumatic types, or an electrically amplified ammeter for the electronic types.

Reliability Spill Risk - The reliability of a recorder is good if properly maintained. Since they do not serve as a part of a control loop, then a failure would only affect the record itself.

Potential Failure Modes - Failure would be confined to a faulty chart drive or a malfunctioning pen drive.

Effects of Failure - No other controls would be affected by failure. Only incorrect records would result.

Alternatve Procedure - No alternate procedure would be required, unless the failure threatened to be long term, then manual recording would have to be done.

11211/04 Pressure Switch

Description and Purpose - Basically, this presusre instrument works on the same principle as a pressure transmitter whereby the movement of a bellows or capsule operates a switch. Different pressures require different elements. However, each has its own range and the set point or trip point can be adjusted within that range.

The purpose of the pressure switch is to draw the attention of operating personnel to the fact that a predetermined pressure has been reached.

Reliability Spill Risk - These instruments are considered fairly reliable. However, if one was to fail, it would not

initiate the appropriate function or alarm. Depending upon the application, the consequences of this could range from a high pressure in the system, to the cavitation of and damage to a pump. The risk of spill is minimal since the only source of pressure are the centrifugal pumps which usually have a shut off pressure well below the maximum for the piping, and fittings in the system.

Potential Failure Modes - As with any pressure instrument, the measruing element is subjected to fluctuations which eventually will fatigue the metal. This, together with corrosion, is the most common cause of failure.

Effects of Failure - By not alerting personnel to a potential pressure build up, the effects could be overpressurization of other equipment. No chain reaction within a control loop is envisaged.

Alternate Procedures - Immediate replacement by another switch would be the most effective alternate procedure.

11211/05 Alarm

Description and Purpose - The alarm in question would probably be one in a bank of alarms called an alarm annunciator. These would be a series of engraved translucent windows, back-lighted in the event of an alarm condition. The light will flash and an audible signal such as a bell or buzzer would sound. The physical acknowledgement of the alarm by pressing an appropriate button will silence the audible signal and steady the light. The light will not extinguish until the alarm condition has been corrected.

Reliability Spill Risk - The reliability of these annunciators is considered good apart from the life of the lamps. A test button is provided so that periodic tests can be carried out to determine if any lamps have failed.

Potential Failure Modes - As mentioned, lamps have a limited life. These, together with the occasional relay failure, are the potential sources of failure.

Effects of Failure - The failure of an alarm to call the attention of an operator will mean a delay in rectifying the cause of the alarm.

Alternate Procedure - No alternative procedures are envisaged since failure goes undetected.

11212 Flow Rate Controller

The most common type of pump driver employed on VLCCs is the steam turbine. This type of driver has the advantage of variable speeds, thus being able to control the rate of pumping over a fairly large range. Only those controls associated with the pump and its driver are considered here.

11212/01 Speed Indicator

Description and Purpose - A dial type tachometer is driven either directly from the drive shaft of gear box or from an electrical impulse generated by a transmitter mounted on the drive shaft.

This instrument would be calibrated in revolutions per minute related to the speed of the pump.

Reliability Spill Risk - No spill risk is envisaged and the reliability is considered good.

Potential Failure Modes - With the mechanical drive type of instrument, failure would most likely be the drive cable. The electrical type could suffer from dirty contacts in a pump room environment.

Effects of Failure - Lack of speed indication would of course, deprive the operator of a means of estimating the quantity of oil being pumped.

Alternate Procedure - A reduction in speed, while a repair is affected, would be the most acceptable alternative procedure.

11212/02 Speed Regulator

Description and Purpose - A globe-type valve in the steam supply line to the turbine would be the normal method of regulating the speed.

Potential Failure Mode - Leaking glands would be the most common mode of failure. A valve could fail in the fully-open position in the extreme case of a mechanical breakage.

Effects of Failure - A badly leaking gland would involve the shutting down of the operation unless a bypass system is installed. If a valve failed in the fully open position, overspeeding of the pump would result.

Alternate Procedure - A bypass is an obvious alternate, if installed; otherwise, no alternate procedure is possible.

11213 Pump Protection Devices

As with any large and expensive installation, the minimal cost of protection devices is well worth the investment.

11213/01 Overspeed Trip

Description and Purpose - The obvious purpose of this device is to protect the pump and its driver from excessive speed. A ball and spring centrifugal element in the governor gives the signal which shuts down the steam supply.

Reliability Spill Risk - This instrument must be a reliable type. However, its failure would cause damage to the pump and/or its driver. The overspeeding of the pump would increase the quantity of oil being moved. This together with coincidental states of tank filling and booster pumping could result in a spill.

Potential Failure Mode - A sticking governor caused by dirt combined with old oil and grease is a potential source of failure. Other sources of potential failure are damage or corroded mechanical linkage.

Effects of Failure - If other protective devices failed to effect a shutdown, the failure of the overspeed switch could result in serious impeller and bearing damage to both the pump and the steam turbine.

Alternate Procedure - The manual shutting down of the system would be the most effective alternative procedure.

11213/02 Temperature Switch

Description and Purpose - A flexible capillary tube, liquid or gas filled, transmits the signal from the temperature sensing bulb at the pump to the remote switch. The switch is actuated by the movement caused by the expanding gas or liquid in the thermal system. Adjustment of the set point within a given range is generally a feature of this instrument.

Because of the nature of the equipment it is to protect, this instrument should be mounted away from any vibrations.

Reliability Spill Risk - If failure were to occur, then the pump and/or its driver could suffer damage - a spill local to the pump could happen.

Potential Failure Mode - The constant vibrations inherent in the pumping installation could fracture the capillary tubing. If this were to happen, the switch would not be initiated in the event of high temperature.

Effects of Failure - High temperature in the pumping system would, in the event of this instrument failure, result in damage to the pump and any adjacent piping equipment.

Alternate Procedure - Only where it is obvious to an operator that temperatures are excessive, can the alternative manual shutdown be initiated.

11213/03 Low Lube Pressure Trip

Description and Purpose - For the description of this instru-

ment, refer to 11211/04. The purpose of this application is to protect the pump and its driver from lack of lubrication. The pressure switch continuously monitors the lube oil distribution system to the bearings on the pump and driver.

Reliability Spill Risk - Good reliability must be a factor in the selection of this instrument. The possibility of a spill is minimal with the failure of this instrument.

Potential Failure Modes - Blocked pressure lines to the instrument could cause the nondetection of low pressure.

Effects of Failure - The effects of the failure of this switch would not be immediately apparent. Eventually, the bearings of the pump and driver would seize and cause considerable damage.

Alternate Procedure - There is no alternative procedure apart from manual lubrication and shutdown if the fault is visually detected.

11215/05 Alarm

Refer to 11211/05.

11220 Switch Tanks on Tanker

The class of tanker being considered in this study would have a central control room where tank levels, valve and pump controls would be displayed. It is from this control point that operators would switch tanks to the suction of the cargo pumps. The continuous monitoring and display

of levels in each of the ship's tanks informs the operator when to change from one tank to another. This would be done by remotely opening and closing the appropriate tank valves.

11221 Tank Level Monitor

11221/01 Level Indicator

Description and Purpose - Float type level measurement is used in ship's tanks but these are susceptible to fouling with crude sludge which affects the buoyancy of the float.

A further, less expensive but more reliable method is the "Metri-Tape." This takes the form of a hollow plastic tape attached to the side of the tank. As the level rises, the tape is squeezed and two wires running the length of the tape make contact. A simple resistance measuring circuit transmits the level to remote indicators in the control room.

The most widely used system of level measurement in ship's tanks works on the pneumatic back pressure principle. Briefly, the pressure required to pump air into the bottom of a tank having liquid in it can be related to the level of liquid in that tank. However, since crude oils vary in specific gravity some method of compensation is employed. Two air pressure points in the tank are used with a known distance between them. The difference in the pressures together with the known distance between them, gives a specific gravity correction factor. The back pressure transmitted to the control room indicates the tank levels on panel-mounted indicators.

Reliability Spill Risk - Since this study deals only with the offloading of oil from a tanker and therefore, the emptying of tanks, there can be no spill risk attached to this instrument at the tanker itself.

Potential Failure Mode - Failure of the pneumatic feed-back system due to tubing corrosion and fracture would be the main cause of malfunction.

Effects of Failure - The operator would be deprived of remote indication of the levels in the tank(s). In most cases, the remote readings would indicate zero; therefore, a failure would be obvious.

Alternate Procedure - It is common to employ more than one of the level measuring devices described above. If all else fails, resort to measurement by manual dipping.

11221/02 Manual Dipping

Description and Purpose - This method of level measurement calls for hand dipping of the tanks through hatches in the ship's deck, sometimes referred to as ullaging. The readings are relayed over walkie-talkie radio on the control room.

11222 Valve Line Up Controller

The equipment involved in this procedure is the same as that discussed under 11102 and reference should be made to that section.

11223 Valve Line Up Monitor

The equipment involved in this procedure is the same as that discussed under 11101 and reference should be made to that section.

11300 Shutdown Tanker System (Fig. 2-7)

11310 Stop Pumping

The equipment associated with this procedure is the same as that discussed under 11210 and reference should be made to that section.

11311 Pressure Monitor

Refer to 11211.

11312 Flow Rate Controller

Refer to 11212.

11313 Pump Protection Devices

Refer to 11213.

11320 Displace Oil from Hoses/Loading Arms

To avoid spilling oil on the ship's deck when the hoses or loading arms are disconnected from the ship's manifold, a procedure of drainage and/or blanking-off must be followed. The displacement of oil in hoses under normal conditions is not required. Refer to 33CFR 150.421.

11321 <u>Pressure Monitor</u>

11321/01 <u>Pressure Indicator</u>

This instrument is identical to that described under section 11211/01. However, the purpose of this pressure gauge is as follows. This gauge will indicate the absence of positive pressure in the ship's manifold, and therefore, that it is safe to disconnect the manifold.

11322 <u>Hose/Loading Arm Drain</u>

11322/01 <u>Manual Procedure</u>

Following the completion of cargo discharge the oil in the ship's manifold is drained back through the ship's piping. Where the DWP is a Sea Island with loading arms these are also allowed to drain back through the ship's piping. In the case of the SPM type of DWP, the value at the end of each hose is closed before disconnection from the manifold takes place. After disconnecting an SPM hose from the tanker manifold, a blank flange is bolted on to the end of the hose. A small "telltale" valve on the manifold indicates when drainage is completed.

11330 <u>Emergency Pump Shutdown System</u>

In the event of an emergency, rapid shutdown of the ship's pumps may be necessary. A system is usually installed which will shut off the steam supply to the turbines. Switches positioned at the ship's manifold and in the control room will actuate a solenoid valve which in turn will close a valve in the steam supply line to the turbines.

11330/01 <u>Midship's Remote Pump Shutdown Switch</u>

<u>Description and Purpose</u> - Strategically positioned at the

manifold for easy access, but also protected against the environment and accidental operation, this switch would remotely close the turbine steam supply valve.

Reliability Spill Risk - The reliability of this control must be good, otherwise failure to initiate a shutdown could definitely perpetuate a spill or increase the risk of one.

Potential Failure Mode - Corrosion or fracture of pneumatic tubing would be the main causes of failure. However, a built in fail safe feature would be an asset.

Effect of Failure - Delay in initiation of pump shutdown.

Alternate Procedure - The only safe alternative, depending upon the degree of the emergency would be to manually shut down the pumping system in the pump room. Another alternative would be to close the manifold valves and rely on the protection devices to effect the shut down of the pumps. This method carries with it the risk of equipment damage.

11330/02 Control Room remote Pump Shutdown Switch

Description and Purpose - This control is the same as that described under 11330/01 except that it is mounted on the control panel in the control room.

11340 Close Tanker Valves

Refer to 11100.

11341 Valve Line Up Monitor

11341/01 Remote Indicator

Refer to 11101/01.

11341/02 Local Indicator

Refer to 11101/02.

11342 Valve Line Up Controller

11342/01 Push Button Remote

Refer to 11102/01.

11342/02 Manual Local

Refer to 11102/02.

11342/03 Push Button Local

Refer to 11102/03.

11342/04 Valve Actuator

Refer to 11102/04.

11400 Tanker Communication System (Fig. 2-8)

Communications within the tanker during operations, i.e., between personnel on deck and those in the control room pump room is by portable two-way UHF-FM radios. Aboard ship the sound-powered telephone links the various control and operating rooms (Refer to CRF 46 Part 113.30).

Communications between the tanker and the deepwater port during approach would be over a VHF-FM radio system. During docking and unloading operations, two-way portable FM radios are used, operating on a different channel from that used on the tanker.

11410 Radio
11410/01 VHF-FM (Marine)

Description and Purpose - Communications equipment and facilities on a deepwater port must meet the requirements of 47 CFR 81 and 83 and each portable means of communication used must be certified under 46 CFR 111.30-5 for operation in a Group D, Class 1, Division 1, atmosphere.

The purpose of the VHF-FM is to communicate the tankers arrival within the stipulated vicinity of the DWP and to arrange arrival and docking schedules.

Reliability Spill Risk - These radios have a high degree of reliability within their design range. No risk of a spill on failure since this system is not used for transfer operations.

Potential Failure Mode - Component and circuitry failure are the most common mode of failure.

Effects of Failure - Loss of communications.

Alternate Procedure - A backup short range radio when within range would be the alternative procedure to follow.

11410/02 Walkie-Talkie

Description and Purpose - Frequency modulated UHF-FM, short range, two-way transceivers which are hand held, usually having two channel selection. Their purpose is communication between the personnel on deck and deck officers during preparations for unloading.

Reliability Spill Risk - High reliability, if not abused. No direct spill risk involved; indirect risk of spill through loss of communications.

Potential Failure Mode - Components and circuitry failure are most common. Batteries running down.

Effects of Failure - Loss of local communications.

Alternate Procedure - Replacement of faulty set or replacement of batteries.

11420 Voice

11420/01 Sound Powered Telephone

Description and Purpose - Located at strategic location throughout the tanker, this system provides the basic communication system. The advantage of this system is that no power source is required. Apart from the call-up signal which utilizes a hand-operated generator, the system is sound powered (Refer to CFR 46 Part 113.30).

Reliability Spill Risk - Good reliability if of first class quality. Loss of communications could result in indirect risk of oil spill.

Potential Failure Mode - Component failure, particularly the hand generator for call-up.

Effects of Failure - Loss of local communications.

Alternate Procedure - Resort to walkie-talkie radio communications.

12000 MOVE OIL THROUGH OFFSHORE PIPELINE (Figs. 2-9 & 2-10)

12100 Line-Up Offshore System (Fig. 2-11)

Although the control systems associated with manipulation of Hoses, Loading Arms, and Corrosion Inhibition are not directly related to the control of the Oil Transfer System, they are discussed here as a matter of interest so that a complete and overall view of a Deepwater Port and its major components is maintained.

Hoses and Loading Arms - An exhaustive search has revealed that it is not normal to have controls on the hoses connecting an S.P.M. to a tanker manifold. The butterfly valve installed at the manifold end of hoses is for isolation when disconnected and it does not play a part in the control of oil transfer.

The fully articulated loading arms installed on modern terminals are hydraulically driven by a system of pistons, cylinders, rams and cables. Three movements of the arms are powered by these systems:

a) Slewing of the complete arm
b) Raising and lowering of the inboard section
c) Raising and lowering of the outboard section

The controls which first of all select the arm to be maneuvered and then perform the other movements are concentrated on a panel usually in a small building adjacent to the bank or arms. Owing to the vast freeboard of the tankers, it is common to find a set of duplicate controls mounted on a pendant box located at the end of at least two of the arms, the procedure being to maneuver the first arm to the ship's rail from the control panel on the platform and then perform the rest of the operation from the remote pendant control on the ship's deck.

To save time, a Quick Connect/Disconnect Coupling (Q.C.D.C.) may be fitted to the end of each arm. This eliminates

the time involved in making bolted connections. This coupling is also hydraulically operated from the same control locations as the arms.

Each arm is fitted with a set of "Drift Switches" which in the event of ship movement beyond certain limits, will initiate alarms. (Fig. 2-12)

It should be noted that all loading arms are fully balanced by counterweights in an EMPTY condition and under no circumstances must attempts be made to operate them while full or partially full of oil.

Corrosion Inhibition - Corrosion Inhibition in large crude oil pipelines is not considered normal; however, where quantities of water may be expected to be mixed with crude oil have a high H_2S content, internal corrosion protection of the pipeline may be considered necessary. Two methods are employed using an amine base compound which gives a chemical protective barrier coating to the inside surface of the pipe. The first method is to introduce a high concentration slug, usually between "pigs," into the pipeline at periodic intervals. The second is to continuously inject a weaker solution of 10 to 50 ppm of the inhibitor during flowing conditions.

12110 Hose/Loading Arm Connection to Tanker (Fig. 2-12)

In the case of the connection of hoses from an S.P.M. to a tanker, the hoses will be full from the pervious operation. The procedure is for launches to bring the floating hoses along side the tanker and assist in the handling of the hoses to the ship's manifold.

Prior to the unlocking of the Loading Arms, checks must be made to ensure they are empty. A low range pressure gauge at the base of each arm will indicate the level of oil, of any, in the loading arm. It should also be an operational procedure to open the drain valves at each arm just as a safeguard against a faulty pressure gauge.

12111 Oil In Hose/Loading Arm Detector

12111/01 Pressure Indicator

Description and Purpose - This instrument is identical to that described under Section 11211/01, however, the purpose of this gauge is as follows:

The following applies to loading arms only, hoses are not fitted with pressure gauges. Its low range is specifically selected to reflect the level of oil in the loading arm. During normal pumping operations, this gauge should be isolated to avoid overpressure damage.

12112 Hose/Loading Arm Drain

12112/01 Manual Procedure

Hoses are not normally drained of oil except prior to a tropical storm (Refer to Fed. Reg. 33. 150.421). The following applies to Loading Arms only.

Operators must manually open valves at the base of each loading arm prior to unlocking the arm stowing mechansim. Not until all oil has been drained from the arm must the drain valve be closed.

12120 Line-Up Valves

The large operational valves found on platform complexes are usually electric motor operated. This operator, generally called an actuator, is fitted to all valves of 12 inches and over.

12121 Valve Line-Up Controller

12121/01 Push Button Remote

Description and Purpose - This control would be located in the central control room of the platform complex. It would be mounted on a control panel which displays a mimic diagram of the oil transfer system and would constitute at least two illuminated push buttons for the basic open and close commands to the valve.

Feedback from the actuator limit switches illuminates the switches in a sequence indicating fully closed, open or with both buttons illuminated while between the two limits.

Reliability Spill Risk - The reliability of this remote control is generally good and with the feedback indication of the valve position, no risk of a spill is considered.

Potential Failure Modes - Wire connections to the switch are the most common mode of failure. Lamps also have a limited life and must be considered as a mode of failure.

Effects of Failure - Misleading information resulting from a failure could cause oil to be routed incorrectly.

Alternate Procedure - Failure of remote controls would call for operating the valve locally.

12121/02 Push Button Local

Description and Purpose - Switches are built into the valve actuator which initiate the opening, closing and stopping of the valve. Usually, these controls are of a sturdy manufacture and sealed against the elements.

Reliability Spill Risk - Under normal operations no spill risk is envisaged on failure. If the valve is to be closed in an emergency, then resorting to manual closing would take longer and the spill risk would be increased.

Potential Failure Modes - Failure would be through lack of use, where moving parts would seize due to corrosion.

Effects of Failure - As described above, failures would only result in a time delay while the situation is remedied or the valve is operated manually.

12121/03 Manual Local

Description and Purpose - This item is the hand wheel provided on the valve to manually open or close it. With large size valves, gearing is provided to reduce the effort required.

Reliability Spill Risk - Since this is a mechanical operation which takes place at the valve, no spill risk is considered.

Potential Failure Modes - The most common failure would be the seizing of gears and other moving parts.

Effects of Failure - Failures described above would result in a time delay while the cause is determined and the situation corrected and brought back to normal.

Alternate Procedure - No alternative procedure for the closing of a valve is possible, if both the actuator and hand wheel are inoperative.

12121/04 Valve Actuator

Description and Purpose - The actuator varies in size and complexity according to the size and function of the valve. Basically, it consists of an electric motor, a gearing system, limit switches and local push button controls. All electrical parts are housed in a explosionproof enclosure in accordance with CRF 46.111.80.

The function of the actuator is to open and close a valve.

Reliability Spill Risk - None during line-up.

Potential Failure Modes - Burnt out motors are a common failure caused by limit switch failure or by seized gearing or valve disc.

Effects of Failure - Failure of an actuator would result in a time delay in operating a valve by hand.

Alternatie Procedure - The only alternative is to operate the valve manually.

12121/05 Limit Switches

Description and Purpose - Limit switches can take many forms. They are driven from the gearing of the actuator and can be set to make or break contacts at any time during the travel of the valve. Limit switches ensure that the valve actuator stops when the limits of open or close have been reached. They also provide feedback for remote indication of valve positions and the switching necessary for interlocks.

Reliability Spill Risk - Fairly serious consequences could result with the failure of limit switches and mis-routing of oil could end in a spill.

Potential Failure Modes - Dirty contacts or the effects of corrosion are the main causes of failure.

Effects of Failure - Wrong information fed back to an operator or the failure to effect an interlock could have a chain reaction resulting in the misrouting of oil.

Alternate Procedure - Depending upon the effects of failure, various alternate procedures are possible. Primarily, these would involve the closing of other valves in the piping system.

12122 Valve Line-Up Monitor
12122/01 Remote Indicator

Description and Purpose - The lamps incorporated in the Push Button Remote (11222/01) are the remote indication of the valve position.

Reliability Spill Risk - Although limited in life, the failure of a lamp would result in minimal risk of an oil spill.

Potential Failure Modes - The failure of the lamp itself is the most common cause. Secondary to this would be the wire connections to the lampholder

Effects of Failure - Failure may create a short delay in operations while it was determined by the lamp test button that the lamp had in fact failed

Alternate Procedure - A check of the local indicators would soon confirm the valve position.

12122/02 Local Indicator

Description and Purpose - Valve actuators incorporate a local position indicator. This indicator is driven by the gearing in the actuator. On valves employing a rising stem, a rod fitted to the top of the stem gives a positive indication of the valve state.

Reliability Spill Risk - None during line-up.

Potential Failure Modes - Mechanical breakage is the only potential failure mode envisaged.

Effects of Failure - Failure of an indicator would have little effect other than a short delay while the valve position is determined.

Alternate Procedure - Remote indication on the central panel will give the valve position.

12200 Move Oil Through Offshore System (Fig. 2-13)
12210 Establish Flow
12211 Pressure Monitor (Fig. 2-14)
12211/01 Pressure Indicator

This instrument is identical to that described under Section 11211/01.

12211/02 Pressure Transmitter

This instrument is identical to that described under Section 11211/02.

12211/03 Pressure Recorder

This instrument is identical to that described under Section 11211/03.

12211/04 Alarm

This instrument is identical to that described under Section 11211/05.

12212 Temperature Monitor

12212/01 Temperature Indicator

Description and Purpose - This is a local instrument inserted into a pocket in the pipeline which displays the temperature of the pipe contents. Usually a mercury-in-steel type is used where the expansion of the mercury in a stainless steel bulb drives the pointer mechanism. Other types employ the principle of variable electrical resistance with temperature change.

Reliability Spill Risk - Temperature indicators are basically very reliable. No risk of an oil spill on failure.

Potential Failure Modes - Corrosion in the pointer driving mechanism and glass breakage are the most frequent failure modes.

Effects of Failure - Since it is not an element in a control loop, the effect of failure is inconsequential.

Alternate Procedure - Replacement of the faulty instrument.

12213 Flow Rate Monitor (Fig. 2-15)

The monitoring of the flow rate is important to operators on facilities without metering. In this case, the flow rate measuring and controlling instruments provide the only means of knowing the ship's pumping rate, and of exercising some degree of control over it. Without it, the terminal is somewhat at the mercy of the ship's personnel who are not aware of the platform and onshore conditions.

12213/01 Measuring Devices

The measuring devices or primary elements for flow measurements are fully described in the introductory section of this appendix. This application would normally employ an orifice plate.

Reliability Spill Risk - The reliability of the orifice plate is excellent; there is little that can go wrong with it.

Potential Failure Modes - Sludge blockage of the pressure taps in orifice flanges.

Effects of Failure - The potential failure modes described above would result in incorrect flow measurement and control.

Alternate Procedure - Determination and correction of fault by reaming pressure taps.

12214 Flow Rate Controller

12214/01 Flow Indicator

Description and Purpose - This is a remote panel mounted instrument receiving an electrical signal from the flow transmitter.

Reliability Spill Risk - A circuitry failure such as an electrical short in wiring and solid state devices usually results in a malfunction. No spill risk.

Potential Failure Modes - As described in Reliability above, circuitry failure would be most common.

Effects of Failure - Lack of true flow rate indications. If not obviously faulty, operator could be mislead into taking corrective action.

Alternate Procedure - Request ship's estimate of pumping rate and check tank filling rate over a known period of time.

12214/02 Flow Controller

Description and Purpose - This panel mounted electronic instrument receives the signal from the transmitter and compares it with a preset "set-point" and produces a corrective signal to the flow regulator.

Reliability Spill Risk - Again, a circuitry or component failure would result in a malfuction. These instruments usually have built in circuitry which will cause it to fail safe, so no risk of spill exists.

Potential Failure Modes - Circuitry failure would be most common.

Effects of Failure - The fail safe feature would prevent any serious effects and also calls the attention of operators to the situation.

Alternate Procedure - Replacement of whole instrument or component card. Another alternative is to switch to manual control.

12214/03 Flow Transmitter

Description and Purpose - In the case of the orifice plate, the transmitter converts the pressure differential to an electrical signal which it transmits to the indicator and controller in the control panel.

The sonic transmitter converts the speed of the sonic signal into an electrical signal which it also transmits to the panel mounted instruments.

Both these transmitters are field mounted and their enclosure be explosionproof in accordance with CRF 46.111.80.

Reliability Spill Risk - Electric circuitry failure can be common but with the selection of good quality instruments reliability should increase. No spill risk envisaged.

Potential Failure Modes - Circuitry failure would be most common.

Effects of Failure - Faulty signals to the controller would result; in turn this could cause faulty flow regulation.

Alternate Procedure - Replacement of the whole instrument would result in a short reduction of flow rate. While this is done, manual control can be employed.

12214/04 Flow Regulator

Description and Purpose - This component in the flow control loop is the valve in the pipeline which receives the corrective signal from the controller and regulates the flow by either opening or closing. In large pipelines, the conventional type of pneumatically actuated globe valve cannot be used. These are limited in size. Ball valves or parallel plug type are usually employed using a conventional electric motor actuator.

Reliability Spill Risk - The valve itself is considered very reliable; however, the actuator could be troubled by electrical circuitry faults.

Potential Failure Modes - Electrical failures in the actuator as a primary mode, leaking seals in the valve would be considered secondary failure modes.

Effects of Failure - The failures considered in the actuator would probably leave the valve in its last position. Leaking seals could cause "creeping" in the valve which would soon become obvious to the operators.

Alternate Procedure - Resort to manual control while fault is corrected.

12220 Sampling

Although not a control system nor a part of one, automatic sampling is an integral part of any custody transfer installation.

The sample of crude oil taken must be representative of the total cargo discharged. The normal type of instrument extracts a small predetermined quantity for each unit of flow measured either by itself or by the metering system. The sample is automatically contained at the line pressure to prevent the loss of light ends. Normally, the total size of sample taken is between two and five gallons.

12220/01 Sampler

Description and Purpose - Two types of samplers are usually employed on large throughput terminals. The first employs a propeller inserted into the pipeline which drives a small rotating pump, the volume of which is adjustable. In this method, each small sample taken for a given number of propeller revolutions yields a total sample which is representative of the total cargo discharged.

The second system uses the signal from the flow transmitter (12214/03) which will periodically open and close a small valve for a given number of pulses from the transmitter. Again, this results in a total sample which is representative of the total cargo discharged.

12230 Booster Pumps Controls (Figs. 2-16 & 2-17)

The purpose of a booster pump station is to assist the tanker cargo pumps in moving the crude oil to shore storage

tanks. They become necessary when, due to long distances the friction in the submarine pipelines is too great for the ships' pumps to overcome. One of the major difficulties in the design and operation of booster pump stations is that the output from the ship with all its variations of flow rate and pressure due to tank changing and levels, is the input to the booster pumps. Controls are necessary so that the booster pumps can closely follow the variations from the ship. These controls continuously monitor the suction and discharge pressures and the discharge flow rate of the booster pumps, and control the input by regulating control valves.

Apart from these controls on the crude oil system, the pumps and their drivers are fitted with a variety of controls and protective devices.

12231 <u>Pressure Monitor</u>

12231/01 <u>Pressure Indicator</u>

This instrument is identical to that described under Section 11211/01.

12231/02 <u>Pressure Transmitter</u>

This instrument is identical to that described under Section 11211/02.

12231/03 <u>Pressure Recorder</u>

This instrument is identical to that described under Section 112[illegible]/03.

12231/04 Pressure Switch

This instrument is identical to that described under Section 11211/04.

12231/05 Alarm

This instrument is identical to that described under Section 11211/05.

12232 Temperature Monitor

12232/01 Temperature Indicator

This instrument is identical to that described under Section 12212/01.

12233 Flow Monitor

12233/01 Flow Element

This element is described under Section 12213/01.

12234 Flow Rate Controller

12234/01 Flow Transmitter

This instrument is identical to that described under Section 12214/03.

12234/02 Flow Controller

This instrument is identical to that described under Section 12214/02.

12234/03 Pressure Controller

Description and Purpose - This is a panel mounted electronic instrument which receives the signal from the pressure transmitter and a preset "set-point" produces a corrective signal to the signal selector. In all other aspects, the instrument is identical to that described under Section 12214/02

12234/04 Signal Selector

Description and Purpose - This instrument, which is panel mounted, accepts the signals from these sources:

a) The suction pressure controller
b) The discharge pressure controller
c) The flow controller

It selects the signal calling for the greatest correction and passes it on to the regulating valve in the discharge piping.

Reliability Spill Risk - A circuitry or component failure would result in a malfunction. These instruments usually have a built-in fail safe feature. No risk of spill exists.

Potential Failure Modes - Circuitry failure would be the most common.

Effects of Failure - The fail safe feature would freeze the output signal and no further regulation would be possible.

Alternate Procedure - Replacement of parts or whole instrument. Alternatively, manual control would take over for a short while.

12234/04 Flow Regulator

Refer to 12214/04.

12235 Pump Protection Devices

Various built-in protection devices are necessary to prevent damage to the pump and driver. These devices will automatically shut down the pump when a preset point has been reached. Pumps fitted with mechanical seals on the impeller shaft have a system whereby any leakage is channeled to a chamber having a level switch, and when a certain level is reached, the pump will be shut down. A small bleedoff from the chamber will prevent initiation of shutdown by small accumulating leaks which are considered normal. A vibration switch will detect abnormal vibration caused through imbalance of the rotating parts due to accumulated sludge or wax. A differential pressure switch continuously monitors the difference between the suction and discharge pressures and is set to trip at a predetermined high pressure. This indicates that the pipe has been restricted on the downstream side of the pump, probably due to the accidental closure of a valve.

An air eliminator is generally mounted in the pipeline. This has the effect of momentarily slowing down the flow and allowing any air to escape and accumulate at the top of the tank where it is bled off.

Most of these devices which cause a shutdown also initiate an alarm on a remote panel. This not only notifies the operator of the shutdown, but also identifies the cause.

12235/01 Level Switch

Description and Purpose - This is the float and arm type of level switch which operates a mercury switch in an explosionproof enclosure when the critical level is attained.

Reliability Spill Risk - Although normally reliable, the material of the float should be carefully chosen to be impervious to crude oil and its various properties. Otherwise, it is reliable and spill risk is negligible.

Potential Failure Modes - Corrosion and leaking of the float.

Effects of Failure - The pump would continue to run and the mechanical seal would be further damaged. A minor spill may occur.

Alternate Procedure - This will mean the shutdown of the pump for a period of time while repairs were effected

12235/02 Vibration Switch

Description and Purpose - A vibration switch comprises a series of spring steel reeds of varying thickness enclosed in a switch housing and attached to the body of the pump. The set point can be adjusted to the degree of vibration which will cause certain of the reeds to vibrate. The reeds make electrical contact and initiate the shutdown.

Reliability Spill Risk - Failure will probably cause damage to the pump rather than an oil spill.

Potential Failure Mode - Corrosion of the reeds would cause a failure.

Effects of Failure - Whatever the cause of the vibration, if it continues, then the pump and its driver would be damaged.

Alternate Procedure - The cause of the vibration must be determined and any damage rectified. This will put the pump out of service for a period of time.

12235/03 Differential Pressure Switch

Description and Purpose - The principle of pressure measurement by bourdon type as described under Section 11211/01 is used. However, since two pressures are to be measured, two opposing tubes are used and the difference in their movements is the result of the differential pressure. This movement trips mercury switches which in turn initiate the shutdown and alarm.

Other aspects of this instrument are as described under Section 11211/04.

12235/04 Air Eliminator

Description and Purpose - Its function is to eliminate entrained air from the crude oil before it passes through the pump. The principle is the same as the float and arm of a level switch but instead of actuating a switch,

a valve is opened on low oil level and the air is exhausted by line pressure. The valve closes as the level rises.

Reliability Spill Risk - The material of the float must be carefully chosen to be impervious to crude oil. Reliability is considered good but there is a risk of a minor spill in the event of failure.

Potential Failure Modes - Leaking of the float will cause excess air to accumulate and eventually find its way to the pump. A sticking valve could have the same effect if stuck closed or it could cause a minor spill if stuck open.

Alternate Procedure - The closing of an isolating valve installed after the release valve would stop a further spill of oil. The system should be shut down while the air elimination is replaced or repaired.

12235/05 Alarm

This instrument is identical to that described under Section 11211/05.

12240 Relief of Pressure Surges (Figs. 2-18 & 2-19)

The purpose of this system is to protect the piping and equipment from sudden high pressures caused by hammer shocks as a result of rapid valve closure during high flow rates. The large quantity of fluid to be relieved in order to reduce the pressure to a safe level prohibits the use of the conventional type relief valve. The type of relief valve normally installed the "Flexflow" valve manufactured by "Grove". This valve is simple in principle and only has

one moving part - a flexible neoprene sleeve. The line fluid will not flow past this sleeve until there is sufficient pressure to lift it against the pneumatic pressure applied on the outside. The pneumatic pressure, therefore, determines the relieving set pressure.

The size and number of valves to be employed is a function of the quantity of oil to be relieved and the minimum time in which this can be done. Each valve has its own individual characteristics and, therefore, requires individual testing "in-situ" to determine the pneumatic pressure required for a given relieve pressure. In order to do this, isolating valves and pressure test connections are required upstream of each relief valve.

The pressures involved are much higher than the normal 100 psig instrument or maintenance air found on some Sea Islands. Unless a high pressure air system is available, the normal practice is to use an inert gas such as nitrogen in banks of commercially filled containers. A system of leakproof small bore piping and valves supplies the gas pressure from a bank of cylinders to the relief valves. Due to the individual characteristics of the relief valves, the supply to each must be separately adjusted with a pressure regulating valve. A pressure switch monitoring the supply pressure of the gas will initiate an alarm on low pressure. Standby cylinders would then be opened to the system.

The surge vessel, in order to absorb the relieved quantity of fluid in a short period, must be fitted with large vents. To prevent an overflow through these vents, a level switch detects high level in the vessel and causes an isolating valve to close. This same protective system will come into play in the event of pneumatic pressure failure allowing fluid to pass the relief valves.

The following is a short discussion on the conditions necessary to create a surge.

Pressure surges, sometimes called "water hammer", can be created by the rapid opening or closing of a valve, or by the rapid starting or stopping of a pump. If the velocity of the liquid flowing in a pipe is suddenly diminished, then the energy given up by the liquid will be absorbed by compressing the liquid by stretching the pipe wall and by frictional resistance to pressure wave propagation.

"Water Hammer" is a series of pressure pulsations often accompanied by a sound comparable to that of striking the pipe with a hammer. When a valve is closed rapidly against a flowing liquid, the pressure is suddenly increased on the upstream side causing a high pressure wave to travel upstream of the valve. Likewise, on the downstream side, the pressure is suddenly reduced and a vapor pocket may be formed.

This cavity will eventually collapse and produce a high pressure wave which travels downstream of the valve.

A formula has been developed which gives the velocity of the pressure wave in the pipe where the valve has been closed instantaneously.

$$Vp = \sqrt{\frac{K\ g}{\omega} \cdot \frac{1}{1 + \frac{Kd}{Ee}}} \qquad (1)$$

where:

V_p = Velocity of the pressure wave. Ft./Sec.

K = Bulk Modulus of Compressibility
water = 300,000 psi
oil = 2,000 to 225,000 psi

g = Acceleration due to gravity = 32.2 Ft/Sec.^{2}

ω = Specific weight of the liquid lbs./cu. ft.

E = Modulus of Elasticity of the pipe material steel = 30,000,000 psi

d = Inside diameter of the pipe in inches

e = Thickness of pipe wall in inches

The following formula gives the magnitude of the pressure produced by arresting the velocity of liquid in the pipe:

$$p = \frac{\omega V}{g} V_p \frac{1}{144} \qquad (2)$$

where:

p = Pressure in psi

ω = Specific weight of liquid lbs./cu. ft.

g = Acceleration due to gravity = 32.2 Ft./Sec.^{2}

V_p = Velocity of the pressure wave Ft./Sec.

V = Initial Velocity of Liquid Ft./Sec.

The following formula gives the time it takes the pressure wave to travel along the pipe and return to the closed valve.

$$t = \frac{2\ell}{V_p S} \qquad (3)$$

where: t = Total closing time of valve (sec.)

ℓ = Length of pipe (Ft.) **

V_p = Velocity of the pressure wave (Ft./Sec.)

S = Empirically determined multiplier (indicates fraction of total valve closing action affecting the flow velocity = .15*)

* The initial 85% of valve closure does not significantly contribute to the initiation of a pressure surge.

** "ℓ" is the length of line between the valve in question and the origin of flow (storage tank, pump) or the nearest upstream surge suppressor (surge tank, surge relief valve, check valve, etc.)

Equation (3) gives the critical time for the closing of the valve. If the valve closes in a shorter time than "t", then a pressure wave will be created, the magnitude of which is determined by equation (2). It can be seen from equation (3) that the longer the pipeline, the slower the valve closure must be to avoid a pressure wave.

12241 Surge Relief Availability Control

12241/01 Valve Actuator

The purpose is to isolate the Surge Relief system when the tank is getting full.

Description and Purpose - This has to be a quick closing valve, usually a ball type requiring only a 90^{o} turn to close from fully open. The actuator can be of the opposing cylinder type or the hydraulic vane motor type. Either are quick acting and their time of closure can be adjusted.

The signal to close comes to a solenoidvalve in a pneumatic pressure line. The released high pressure air or nitrogen forces the hydraulic fluid into the actuator and the valve is closed.

Reliability Spill Risk - The quality of this valve actuator and the tubing associated with its operation should be of first class quality. Reliability is good; however, failure would result in a spill.

Potential Failure Modes - Fracture of tubing is the most common cause of failure; piston seizure in cylinders occurs occasionally due to non-use.

Effects of Failure - If this valve does not close following a surge condition, the relief tank will continue to fill and oil will spill from its vent.

Alternate Procedure - Manual closure of the valve is the only alternative and will result in a delay . The oil transfer operation should be shut down as soon as possible.

12242 Surge Relief Availability Monitor

12242/01 Level Switch

Description and Purpose - The type of level switch normally used employs the principle of displacers rather than floats. In this particular case, the three displacers, usually made of a ceramic material, hang on a stainless steel wire suspended from a spring. The wire is attached to a steel rod which moves in a non-ferrous tube on the outside of which are magnetic followers connected to mercury switches.

As the level in the tank rises, the displacers become lighter as they are immersed by the liquid, the spring contracts and the steel rod moves, thus, actuating the mercury switches via the magnetic followers.

The housing of the switches must be explosionproof and meet the standards established by CRF 46.111.80

It is usual practice to house the displacers in a "still well", a perforated length of pipe, in order to minimize the affect of turbulence caused by inflow into the tank.

Reliability Spill Risk - Once installed, and as long as good quality level switches with stainless steel wire and fittings and mercury switches have been selected, the reliability is good.

Failure of this switch could result in an oil spill.

Potential Failure Modes - Displacers sticking in the still well would casue this instrument to fail.

Effects of Failures - Failure to detect high level in the tank and initiate the closing of the isolating valve, will continuously cause oil to flow into the tank and eventually spill from the vent.

Alternate Procedure - The pumping operation should be shut down and the valve closed manually.

12242/02 Alarms

This instrument is identical to that described under Section 11211/05.

12243 Relief Valve Pressurization Medium Monitor

The high pressure pneumatic system which keeps the relief valves closed is monitored by pressure guages and switches which will initiate alarms before a critical situation is reached.

12243/01 Pressure Indicator

This instrument is identical to that described under Section 11211/01.

12243/02 Pressure Switch

This instrument is identical to that described under Section 12211/04.

12243/03 Alarm

This instrument is identical to that described under Section 11211/05.

12244 Relief Valve Pressurization Medium Controller
12244/01 Pressure Control Valves

Description and Purpose - In order to maintain the pneumatic pressure at the set pressure required at the surge relief valves a series of pressure control valves are necessary. These valves are small valves which continuously monitor the pressure downstream and, if necessary, will open to allow the higher pressure upstream to bleed through until the desired pressure at the relief valve is achieved.

Reliability Spill Risk - Cost should be no object in selecting the best quality valves available. Given this, reliability is good, however, the risk of a spill does exist on failure.

Potential Failure Modes - Dirt in the pneumatic system could cause a pressure control valve to stick open or closed.

Effects of Failure - If the valve sticks open, the relief valve will be over pressurized and would not function in the event of a surge. If stuck closed, then the relief valve could become underpressured and leak oil into the surge tank.

Alternate Procedure - When detected, the particular relief valve should be isolated and the pressure control valve replaced.

12250 Metering (Fig. 2.20)

Metering is a means of precise quantity measurement which can be used for custody transfer and/or leak detection by comparison with other metering stations. The actual control functions of the metering equipment are covered in Fig. 2-15.

By definition, deepwater ports are built for the VLCC class of tanker and designed to accommodate the large discharge rates achieved by these tankers. Methods of quantity measurement must therefore, also be capable of accommodating the high flow rates. The equipment accepted in the industry as being capable of accurate measurement at high throughputs are turbine meters. These meters have the distinct advantages of being compact, mechanically simple and comparatively long lived.

Turbine meters have inherent performance characteristics such as flow rangeability within tolerable limits of linearity and repeatability. These are generally related to fluid properties such as density, viscosity and vapor pressure, and to the mechanical characteristics of the meter, such as rotor mass, bearing friction, etc. The combination of fluid properties and meter characteristics produces a deviation from an ideal of meter linearity and selection should be governed by an assessment of the characteristics of the turbine meters.

In considering metering at Deepwater Ports, it can be assumed that a high degree of accuracy is desired whether this be for custody transfer measurement or for comparison with onshore metering stations, as a means of leak detection or for both. This high degree of accuracy is only obtainable with frequent proving of each turbine meter during operating conditions. In simple terms, the prover is a mechanical fluid displacement device of precisely known volume. The fluid passing through the meter is also passed through the prover. The resulting comparison of the meter output with the known volume of the prover provides a factor which can be applied to the output readings of the meter.

Subsequent provings will show the drift or linearity of the meter and whether or not it is within the accepted tolerances.

Other factors which must be taken into account are temperature and pressure variations. Turbine meters are viscosity sensitive and for this fact alone temperature correction factors are important. Other effects of temperature variations would be to physically change the dimensions of the meter and/or the prover. Pressure variations will have similar effects by changing the physical dimensions of the meter and prover. The proving of a meter is best done during operating conditions when both the meter and the prover are subject to the same temperature and pressure.

The electrical components associated with metering have reached a high degree of sophistication and complexity, and the use of computers is becoming more and more necessary.

12260 Pigging (Fig. 2-21)

Crude Oil Transfer Systems may be provided with pipeline pigging systems for cleaning the interior walls of the pipeline, displacing the crude oil in the transfer system with seawater or for segregating (batching) two or more grades of crude oil transferred through the system simultaneously.

Pigs are readily available in three different shapes; spheres, cylinders and discs (refer to Appendix E for manufacturer's information).

The components of a pigging system are a launching barrel, a receiving barrel, launcher and receiver pipline valves, pig detector switches, pig diverter fittings and interconnecting small diameter piping to control crude oil flow upstream and downstream of the pig at the barrel.

Pigs move through the piping system as a result of the differential pressure which exists across the pig upstream and downstream. The velocity at which most pigs move through a system, at least for large diameter piping, should be in the order of five to six feet per second minimum.

Description of Pig Types - The following is a brief description of the three types of pigs readily available and which could be used for Deepwater Port Oil Transfer system service.

Pipeline Spheres - Pipeline spheres are hollow shell spheres fabricated of natural rubber, neoprene, nitrile, polyurethane or other materials compatible with the carrier liquid. The sphere is filled with glycol or other liquid suitable for the service under pressure so that the outside diameter of the sphere is slightly larger than the inside diameter of the pipeline. The sphere is then forced into the pipeline under pipeline fluid pressure, slightly elongating the sphere. This tight or "interference" fit provides the seal between the pipe wall and the sphere to prevent excessive "leakage" of carrier liquid past the sphere as it moves through the system.

Pipeline Cylinders - Pipeline cylinders are solid cylinders usually fabricated of polyurethane. Most cylindrical pigs are "bullet" shaped to assist in negotiating pipeline bends and other fittings. The circumference of some cylindrical pigs are manufactured with criss-crossing bands of hard rubber material which facilitates and improves the "cleaning" action of the pigs. Cylindrical type pigs have the capability of negotiating very short radius turns and, further, can be used to clean or segregate product in pipeline systems having up to three line size changes in a given run.

Pipeline Discs - Pipeline Disc Pigs consist of a single or multiple sets of discs, usually cup shaped, which are connected end to end by articulated joints. Wire brushes, if the pigs function is cleaning, are placed between the cupped discs. The wire brushes are spring loaded radially for the purpose of providing a force against the pipe wall so that the necessary cleaning action can be

developed as the pig moves through the pipeline. For product segregation (batching) additional cupped discs are substituted for the brushes.

Pipeline discs may be used for other purposes such as line scraping or gauging wherein scraper cups and discs are employed to clean "encrusted" pipe walls (that brushes cannot clean) or shear welding icycles and other internal pipe projections to a given gauge (diameter).

Of the three types of pigs described above, the pipeline sphere is most universally used for Deepwater Ports service. It is expected that spheres will continue to be the dominant pigs used for Deepwater Port Service, hence, the following description of a pigging operation will be limited to spheres.

Pigging Operation - A brief description of a batching operation using pipeline spheres is presented below. It should be noted that a step-by-step procedure for a particular pigging operation may be somewhat different than herein below described due to the type of pig employed or the particular receiver/launcher piping arrangement selected or the type of product transferred. The batching operation described is keyed to the launching and receiving diagram (Figure 2-21).

Launching

1. Open the drain line and ensure that the launching barrel is completely empty of oil.

2. Open the hinged closure and insert spheres of correct size for the pipeline, close the hinged closure and secure.

3. Close Valve B and open Valve A.

4. Lift launching pin and let the sphere roll down the barrel into the pipeline past Valve A.

5. Open bypass Valve M to pressurize the barrel and to apply positive pressure on the sphere to move it past the tee connection at Valve B.

6. Close bypass Valve M and Main Valve A.

7. Open Valve B to allow flow from the tanker to push the sphere through the main pipeline.

Receiving

1. Valve D should be closed and Valve C open to allow the liquid ahead of the sphere to be routed into the pipeline.

2. When the first sphere detector signals the arrival of the sphere, Valve D is opened and Valve C closed to allow sphere to move into the barrel. The drain connection in the receiving barrel is also opened to drain liquid from the barrel.

3. When the second sphere detector located downstream of Valve D signals the passing of the sphere, Valve D is closed and Valve E opened to allow liquid behind the sphere to flow into the other line.

4. After Valve D is fully closed, the drain connection in the receiving barrel is left open and liquid allowed to drain out until the barrel is empty. Liquid drainage

should be into an open funnel so that a visual check on the draining operation can be maintained and to ascertain when the barrel is completely drained.

5. Remove the sphere from barrel for cleaning, storage and reuse.

12300 <u>Shutdown Offshore System</u> (Fig. 2-22)

12310 <u>Booster Pumping Shutdown</u>

The sequential shutting down of a booster pumping station can begin when the ships' cargo pumps are replaced by the small stripping pumps. At this stage, due to the smaller quantities involved, only one booster pump would be in operation.

12311 <u>Pressure Monitor</u>
12311/01 <u>Pressure Indicator</u>

Refer to 11211/01

12311/02 <u>Pressure Transmitter</u>

Refer to 11211/02

12311/03 <u>Pressure Recorder</u>

Refer to 11211/03

02311/04 <u>Pressure Switch</u>

Refer to 11211/04

12311/05 Alarm

Refer to 11211/05

12312 Temperature Monitor
12312/01 Temperature Indicator

Refer to 12212/01

12313 Flow Monitor
12313/01 Flow Element

Refer to 12213/01

12314 Flow Rate Controller
12314/01 Flow Transmitter

Refer to 12214/03

12314/02 Flow Controller

Refer to 12214/02

12314/03 Pressure Controller

Refer to 12234/03

12314/04 Signal Selector

Refer to 12234/04

12314/05 Flow Regulator

Refer to 12214/04.

12315 <u>Pump Protection Devices</u>

12315/01 <u>Level Switch</u>

Refer to 12235/01

12315/02 <u>Vibration Switch</u>

Refer to 12235/02

12315/03 <u>Differential Pressure Switch</u>

Refer to 12235/03

12315/04 <u>Air Eliminator</u>

Refer to 12235/04.

12315/05 <u>Alarm</u>

Refer to 12211/04.

12320 <u>Pack System</u>

12321 <u>Valve Line-Up Indicator</u>

12321/01 <u>Remote Indicator</u>

Refer to 12122/01

12321/02 <u>Visual Check</u>

Refer to 12122/02

12322 <u>Valve Line-Up Controller</u>

12322/01 <u>Push Button Remote</u>

Refer to 12121/01.

12322/02 Push Button Local

Refer to 12121/02

12322/03 Manual Local

Refer to 12121/03

12322/04 Valve Actuator

Refer to 12121/04

12323 Pressure Monitor

12323/01 Pressure Indicator

Refer to 12211/01

12323/02 Pressure Transmitter

Refer to 11211/02.

12323/03 Pressure Recorder

Refer to 11211/03

12323/04 Alarm

Refer to 11211/04

12330 Drain and Slops Handling (Fig. 2-23)

The drain and slop system is not directly related to the oil transfer system but since its malfunction could result in a spill of crude oil, it has been included in this study.

The purpose of this system is two-fold, primarily it deals with the crude oil drained from the loading arms during normal operations, secondly, it collects surface water which could be contaminated with crude oil. An automatic pumpout system empties the tank(s) into the main crude system. In order to avoid overpressuring the transfer system with the automatic pumpout, the system must remain open to a storage tank onshore. If this is not possible, the automatic feature must be disposed of and the emptying of the slop tank becomes a manual operation.

12311 Drain Tank Level Monitor

12331/01 Level Switch

Refer to 12242/01

12331/02 Alarm

Refer to 12211/04

12340 Emergency Shutdown System (Fig. 2-24)

The emergency facility, although rarely used, must be available and able to perform its function at any time. Not only during dynamic conditions, but also during periods of no flow. The actuating medium, like the surge system, is a high pressure pneumatic supply, continuously monitored for availability. The actual closure of the valve must be timed such as to avoid the creation of a surge pressure wave. Refer to Section 12240 - Relief of Pressure Surges.

The valve would be a ball type requiring only a 90^{o} revolution to travel from fully open to fully closed. The actuator would be hydraulically driven and the primary energy would be provided by compressed air or nitrogen.

12341 Valve Position Monitor

12341/01 Remote Indicator

Description and Purpose - This remote indicator of valve position is identical to that described under Section 12122/01. However, the switches on the actuator are mechanically initiated by the movement of the valve.

12342 Valve Line-Up Controller

12342/01 Valve Actuator

Refer to 12241/01

12343 Valve Actuating Medium Monitor

12343/01 Pressure Switch

Refer to 12231/04

12343/02 Alarm

Refer to 12211/04

12400 Communication System (Figs. 2-25, 2-26, and 2-27)

The communication link between the offshore and onshore facilities has to handle both voice and data information. Two distinct types of communication are used: submarine cable and radio. The distance involved has a bearing on the choice. For those DWP's where offshore facilities are a few miles from shore, submarine cables become uneconomical, and all communications would be accomplished over a radio system. Shorter distances generally involve both radio for pure voice communciation and submarine cable for voice (telephone) and data transmission. Where large

quantities of complex data are involved, the use of a multiplex coded system reduces the number of submarine cable conductors required.

The direct wire type of submarine cable where each function requires its own individual circuit is simple and uncomplicated. However, the number of circuits is limited by the physical size of the cable.

An alternative method used with submarine cables is to code the signals in such a way that a number of functions can be transmitted over a single conductor. This system requires an encoder and decoder at each end of the submarine cable.

Where distances are so great that a radio link has to be used for all communication, a similar system of signal coding or decoding will be required.

12410 Voice
12411 Wire
12411/01 Telephone

Description and Purpose - A standard "Private Automatic Branch Exchange" (P.A.B.X.) comprising of a central exchange with a system of stations distributed throughout the Deepwater Port, both on and offshore. Those stations in hazardous areas should be explosion proof. The purpose is to provide a verbal communication system.

Reliability Spill Risk - Reliability of a good quality system is very high. No direct risk of an oil spill or failure.

Potential Failure Modes - Component and circuitry failure are most common.

Effects of Failure - Loss of local verbal communications

Alternate Procedure - Use back-up radio communications.

12411/02 Submarine Cable

Description and Purpose - The link between the onshore and offshore facilities which carries the various types of voice and data communication signals. In order to protect the cable from mechanical damage, from dragging anchors, etc., it should be either buried in a trench or jetted into the seabed after installation. The specification for the multi-core cable should include a continuous P.V.C. outer sheath covering twisted steel wire armouring for strength and each individual conductor must be P.V.C. insulated.

Reliability Spill Risk - A submarine cable probably suffers the highest risk of damage during installaiton. Following a successful installation and testing procedure, the reliability is high. Failure could result in loss of communications and the risk of an oil spill is present.

Potential Failure Modes - Mechanical damage by dragging anchors is the most common cause of failure.

Effects of Failure - Loss of communications.

Alternative Procedure - Resort to radio communications.

12412/01 Two-Way FM Portable Radios

Refer to 11410/02.

12420 Data

12421 Wire

12421/01 Encoder

Description and Purpose - Where numerous functions have to be communicated, a multiplex system requiring the coding of data is required. The encoder is the piece of equipment in the system which accomplishes the coding of each separate function for transmission along the submarine cable or radio.

Reliability Spill Risk - If well designed by an experienced company and properly installed and tested, the reliability will be high. There is a risk of an oil spill on failure.

Potential Failure Modes - Component and circuitry failure are the most common modes of failure.

Effects of Failure - Incorrect data communicated which could result in malfunction of valves and other equipment, as well as faulty display information.

Alternate Procedure - Operations should be terminated or reduced and communciations by telephone or radio resorted to.

12401/02 Decoder

Description and Purpose - This piece of equipment in the system decodes the signals coded by the encoder and is usually built into the same enclosure. All other aspects are the same as the encoder, refer to 12421/01.

12421/03 Submarine Cable

Description and Purpose - The specification for this cable is identical to that described under 12411/02. The only difference is that this cable is carrying coded signals.

12422 Radio
12422/01 Encoder

Refer to 12421/01

12422/02 Decoder

Refer to 12421/02

12422/03 R.F. Transceiver

Description and Purpose - This is the microwave radio link which replaces a submarine cable where distances are great. However, it is limited to "line of sight" operation, so if distances dictate it, repeater stations would be necessary. The coded signals from the encoder are received and transmitted to the offshore facilities where they are fed into the decoder, at the same time coded signals can be sent in the other direction.

Reliability Spill Risk - First class equipment which can tolerate a high degree of noise interference is very reliable. The risk of a spill is present on failure.

Potential Failure Modes - Component and circuitry failure are the most common failure modes.

Effects of Failure - Loss of communication and incorrect data could result in an oil spill.

Alternate Procedure - Reduce or shut down operations and resort to back-up verbal communications by V.H.F. radio.

13000 MOVE OIL THROUGH ONSHORE PIPING (Fig. 2-28)

13100 Line-Up Onshore System (Fig. 2-29)

13110 Line-Up Manifold Valves (Fig. 2-30)

The large quantities and variations of crude oil imported at Deepwater Ports from VLCC's necessitates a number of onshore storage tanks. Each tank will have its own pipeline which routes the oil from the shore end of the submarine pipelines. A manifold of valves is required to achieve the interconnection between the submarine pipelines and the tank pipelines.

Each valve is actuated by an electric motor "actuator" which drives the valve through gearing between its limits of open and closed. Each actuator has a system of limit switches.

The primary function of the limit switches is to stop the valve travel in both the fully open and fully closed positions. They also provide the switching which feeds back information to the remote control centers and inhibits the opening and closing of other valves. Each limit switch can be set to open or close at any time during the valve travel.

Interlocks become necessary where types of crude oil must be kept separate and to avoid the accidental opening of valves which would result in contamination.

Interlocks are an electrical circuit which prevents a valve being opened unless one or more other valves are closed.

The limit switches provide the switching that makes electrical interlocking possible.

13111 Valve Line-Up Monitor

13111/01 Remote Indicator

Refer to 12122/01

13111/02 Visual Check

Refer to 12122/02.

13112 Valve Line-Up Controller

13112/01 Push Button Remote

Refer to 12121/01.

13112/02 Push Button Local

Refer to 12121/02.

13112/03 Manual Local

Refer to 12121/03.

13112/04 Valve Actuator

Refer to 12121/04.

13112/05 Limit Switches

Refer to 12121/05.

13120 Tank Selection

13121 Tank Level Monitor (Fig. 2-31)

It is assumed that storage tanks at the shore end of a Deepwater Port facility would be large (in order of 750,000 bbl. capacity) and, therefore, would have floating roofs. Continuous reading level monitoring has reached a degree of sophistication whereby accuracies are claimed in the order to $\pm$ 1/8". With the increase in tank diameters, this amounts to a considerable quantity of oil, thus making custody transfer measurements by this means unattractive. It is, therefore, normal for level instruments to be used only for filling and emptying operations and to alert operators to the dangers of overfilling or emptying.

13121/01 Level Transmitter

Description and Purpose - Basically, a level transmitter consists of a spring loaded drum around which a tape is wound, a float traveling inside a perforated pipe (still well) is attached to the free end of the tape. As the level rises, the slack in the tape is taken up on the drum, the revolutions of the drum are determined electrically and a signal is produced which is transmitted to remote read out indicators. The purpose of the still well is to prevent turbulence affecting the floats and tape, thus producing spurious signals. In order to alert operators to the possibility of overfilling tanks, alarm switches are fitted in the transmitter which initiate alarms when predetermined levels are reached.

Transmitters should be housed in explosion proof housings.

Reliability Spill Risk - The effects of a corrosive atmosphere on electronic cards and components will cause failure. Back-up level instruments minimize the risk of oil spill.

Potential Failure Modes - Failure of electronic components and circuits together with float sticking due to fouling on still well or build up of sludge are the most common causes of failure.

Effects of Failure - Incorrect information of level transmitted to remote indicators. Delays may occur while fault is investigated and rectified.

Alternate Procedure - Due to the time which repair or replacement of faulty transmitter will take manual reading of levels at the tank transmitted by walkie/talkie to control center is the only alternative.

13121/02 Local Indicator

Description and Purpose - The local indicator is driven by the transmitter and is usually located at the bottom of the tank. Depending upon the type chosen, the display is usually digital in terms of feet and inches.

Enclosures should be explosion proof.

Reliability Spill Risk - This instrument is as reliable as the transmitter. Circuitry or component faults caused by corrosion will result in failure. There is no spill risk involved.

Potential Failure Modes - Electronic component failure.

Effects of Failure - Incorrect locally displayed level information would not result in any chain reaction

Alternate Procedure - Repair or replacement of faulty indicator.

13121/03 Remote Indicator

Description and Purpose - Remotely mounted in the central control room, this indicator would usually be the digital type. Where a number of tanks are involved, a selective system would allow the interrogation of one tank level at a time. These displays may not be driven directly by the transmitter output but must be passed through a conversion system making it simpler for the signal to be transmitted and displayed.

Reliability Spill Risk - Well chosen and proven systems and components would be reliable, however, in locations prone to severe electrical storms, even these systems prove unreliable. Incorrect display of level information could lead to an oil spill.

Potential Failure Modes - Electronic component or circuitry failures are most common.

Effects of Failure - Delays in pumping operations may occur while investigations of the failure are made.

Alternate Procedure - If fitted, a test button would confirm circuitry failure. Local reading of tank levels is an alternate which will minimize delays.

13121/04 Level Switches

Description and Purpose - This level switch operates on the principle of a float actuating a mercury switch in

an explosion proof housing. The chamber in which the float operates is external to the tank and can be isolated for maintenance.

Reliability Spill Risk - Generally, very reliable, however, failure of the float will cause failure. An oil spill is possible on failure of a high level switch.

Potential Failure Modes - Corrosion and leaking of the float.

Effects of Failure - The alarm, either high or low, would fail to alert the operator to potential trouble. Also, any automatic action such as the closing of valves or stopping of pumps would not be initiated.

Alternate Procedure - Attention to the tank level displayed in the control center and the taking of action to switch tanks or stop filling would be the alternate procedure to follow.

13121/05 Alarms

Refer to 12211/04.

13122 Tank Valve Controller

13122/01 Push Button Remote

Refer to 12121/01.

13122/02 Push Button Local

Refer to 12121/02.

13122/03 Manual Local

Refer to 12121/03.

13122/04 Valve Actuator

Refer to 12121/04.

13122/05 Limit Switches

Refer to 12121/05.

13123 Tank Valve Monitor

13123/01 Remote Indicator

Refer to 12122/01.

12123/02 Visual Check

Refer to 12122/02.

13200 Move Oil To Onshore Storage (Figs. 2-32 & 2-33)

13210 Booster Pumping

13211 Pressure Monitor

13211/01 Pressure Indicator

Refer to 11211/01.

13211/02 Pressure Transmitter

Refer to 11211/02.

13211/03 Pressure Recorder

Refer to 11211/03.

13211/04 Pressure Switch

Refer to 11211/04.

13211/05 Alarm

Refer to 11211/05.

13212 Temperature Monitor

13212/01 Temperature Indicator

Refer to 12212/01.

13213 Flow Monitor

13213/01 Flow Element

Refer to 12213/01.

13214 Flow Rate Controller

13214/01 Flow Transmitter

Refer to 12214/03.

13214/02 Flow Controller

Refer to 12214/02.

13214/03 Pressure Controller

Refer to 12234/03.

13214/04 Signal Selector

Refer to 12234/04.

13214/05 Flow Regulator

Refer to 12214/04.

13215 Pump Protection Devices

13215/01 Level Switch

Refer to 12235/01

13215/02 Vibration Switch

Refer to 12235/02.

13215/03 Differential Pressure Switch

Refer to 12235/03.

13215/04 Air Eliminator

Refer to 12235/04.

13215/05 Alarm

Refer to 12211/04.

13220 Tank Switching

13221 Tank Valve Line-Up Monitor

13221/01 Remote Indicator

Refer to 12122/01.

13221/02 Visual Check

Refer to 12122/02.

13222 Tank Level Monitor

13222/01 Level Transmitter

Refer to 13121/01.

13222/02 Remote Indicator

Refer to 13121/03.

13222/03 Local Indicator

Refer to 13121/02.

13222/04 Level Switches

Refer to 13121/04.

13222/05 Level Alarms

Refer to 13121/05.

13223 Manifold Tanker Valve Line-Up Controller

13223/01 Push Button Remote

Refer to 12121/01.

13223/02 Push Button Local

Refer to 12121/02.

13223/03 Manual Local

Refer to 12121/03.

13223/04 Valve Actuator

Refer to 12121/04.

13223/05 Limit Switches

Refer to 12121/05.

13230 Metering (Fig. 2-34)

Refer to discussion 12250.

13240 Relief of Pressure Surges (Fig. 2-35)

Refer to discussion 12240.

13241 Surge Relief Availability Control

13241/01 Valve Actuator

Refer to 12241/01.

13242 Surge Relief Availability Monitor

13242/01 Level Switch

Refer to 12242/01.

13242/01 Alarm

Refer to 11211/05.

13243 <u>Relief Valve Pressurization Medium Monitor</u>

13243/01 <u>Pressure Indicator</u>

Refer to 11211/01.

13243/02 <u>Pressure Switch</u>

Refer to 12211/04.

13243/03 <u>Alarm</u>

Refer to 11211/05.

13244 <u>Relief Valve Pressurization Medium Controller</u>

13244/01 Pressure Control Valves

Refer to 12244/01.

13300 <u>Shutdown Onshore System</u> (Fig. 2-36)

13310 <u>Booster Pumping Shutdown</u>

13311 <u>Valve Line-Up Monitor</u>

13311/01 <u>Pressure Indicator</u>

Refer to 11211/01.

13311/02 <u>Pressure Transmitter</u>

Refer to 11211/02.

13311/03 <u>Pressure Recorder</u>

Refer to 11211/03.

13311/04 Pressure Switch

Refer to 11211/04.

13311/05 Alarm

Refer to 11211/05.

13312 Temperature Monitor

13312/01 Temperature Indicator

Refer to 12212/01.

13313 Flow Monitor

13313/01 Flow Element

Refer to 12213/01.

13314 Flow Rate Controller

13314/01 Flow Transmitter

Refer to 12214/03.

13314/02 Flow Controller

Refer to 12214/02.

13314/03 Pressure Controller

Refer to 12234/03.

13314/04 Signal Selector

Refer to 12234/04.

13314/05 Flow Regulator

Refer to 12214/04.

13315 Pump Protection Devices

13315/01 Level Switch

Refer to 12235/01.

13315/02 Vibration Switch

Refer to 12235/02.

13315/03 Differential Pressure Switch

Refer to 12235/03.

13315/04 Air Eliminator

Refer to 12235/04.

13315/05 Alarm

Refer to 12211/04.

13320 Pack System

13321 Valve Line-Up Monitor

13321/01 Remote Indicator

Refer to 12122/01.

13321/02 Visual Check

Refer to 12122/02.

13322 <u>Valve Line-Up Controller</u>
13322/01 <u>Push Button Remote</u>

Refer to 12121/01.

13322/02 <u>Push Button Local</u>

Refer to 12121/02.

13322/03 <u>Manual Local</u>

Refer to 12121/03.

13322/04 <u>Valve Actuator</u>

Refer to 12121/04.

13322/05 <u>Limit Switches</u>

Refer to 12121/05.

13323 <u>Pressure Monitor</u>
13323/01 <u>Pressure Indicator</u>

Refer to 11211/01.

13323/02 <u>Pressure Transmitter</u>

Refer to 11211/02.

13323/03 <u>Pressure Recorder</u>

Refer to 11211/03.

13323/04 <u>Alarm</u>

Refer to 11211/05.

13330 <u>Drain and Slops Handling</u>

This system is primarily installed to deal with the roof drains of the tanks. If it is a practice at the terminal being considered, then it has also to deal with water draw-off from each tank. The slops would be a mixture of oil and water and must be routed to a treatment and disposal system which is not a part of this study.

13331 <u>Drain Tank Level Monitor</u>
13331/01 <u>Level Switch</u>

Refer to 12242/01.

13331/02 <u>Alarm</u>

Refer to 12211/04.

13340 <u>Emergency Shutdown System</u>

Refer to discussion 12340.

13341 <u>Valve Position Monitor</u>
13341/01 <u>Remote Indicator</u>

Refer to 12341/01.

13342 <u>Valve Line-Up Controller</u>
13342/01 <u>Valve Actuator</u>

Refer to 12241/01.

13343 Valve Actuating Medium Monitor

13343/01 Pressure Switch

Refer to 12231/04.

13343/02 Alarm

Refer to 12211/04.

APPENDIX F

SCENARIOS

APPENDIX F - SCENARIOS

F-1. INTRODUCTION

The following scenarios have been chosen to illustrate the results of control system failure during dynamic conditions. They have also been selected because they are three of the few locations on an oil transfer system where an "open end" exists and the failure of a control system would directly result in an oil spill.

F-2. ONSHORE STORAGE

FAILURE OF LEVEL ALARMS ON STORAGE TANK

Assuming maximum filling rate for 750,000 barrel tank = 75,000 B.P.H.

Assume size of inlet/outlet valve to be 36" with an actuator giving a closure rate of 12" per minute.

Assume this valve is a gate valve with characteristics as shown on attached graph (Fig. F-1)

Assume volume of tank roof to be 6,000 barrels.

Assume tank is 66 feet high (to upper rim) and contains approximately 11,360 barrels per foot. Roof travels at 6½ feet per hour.

Primary - High Level alarm in Level Transmitter (13222/01) fails, Operator not made aware of high level in tank. (61.5 feet).

Secondary - High High Level switch (13222/04) fails to actuate automatic shutdown of inlet/outlet valve. (Level switch at 62 feet.)

Level will continue to rise until roof is prevented from rising by structures (approximately 1 foot below rim.) Oil will initially come through the roof vents and support guides and find its way to the roof drains and so to the treatment and disposal system. The roof drain system is unable to accomodate 75,000 B.P.H. so the oil level will continue to rise until it overflows the rim of the tank. At what stage this is visually obvious is indeterminate but for the purposes of this exercise, assume a period of 0 to 15 minutes before action is taken to close the tank valve. The tank valve will take 3 minutes to close. If detection of overflow is immediate, then quantity of oil would be approximately 3,000 Bbls. It can be seen that some 40 minutes must elapse after the primary failure before the start of a spill. This is an extremely long time for the failure to remain undetected bearing in mind that the operator should be paying attention to the remote indication of tank levels and should have some program of tank filling and switching times. The chances of this type of spill would be remote. Figure F-2 shows the magnitude of a spill vs. time for this scenario.

Any spill which did occur would be contained within the diked tank area.

F-3 OFFSHORE

12330

DRAIN & SLOPS SYSTEM

Assume drain and slops tank is full.

Assume level switch failed at high level to start pump and to initiate high level alarm.

Assume unloading of tanker just completed.

The final step before disconnecting the loading arms is to drain the inboard section into the drain and slops tank. The assumption that the level switch failed to start the pump at high level would mean that the tank is full. When the drain valves to the loading arms are opened, the oil will overfill the tank and cause a spill from the tank vent pipe.

The magnitude of this spill could be in the order of 1,500 gallons for every 16" arm drained. Usually 4 loading arms would be used making the maximum amount spilt 6,000 gallons.

F-4. OFFSHORE

SURGE RELIEF SYSTEM 12240

Assume oil importation in progress.

A series of events and failures have to take place in order to result in a spill.

Assume firstly, that the surge system is full and that this state has not been brought to the attention of the operators. Secondly, that a condition of surge pressure must occur in the oil transfer system.

The first assumption can only happen if:

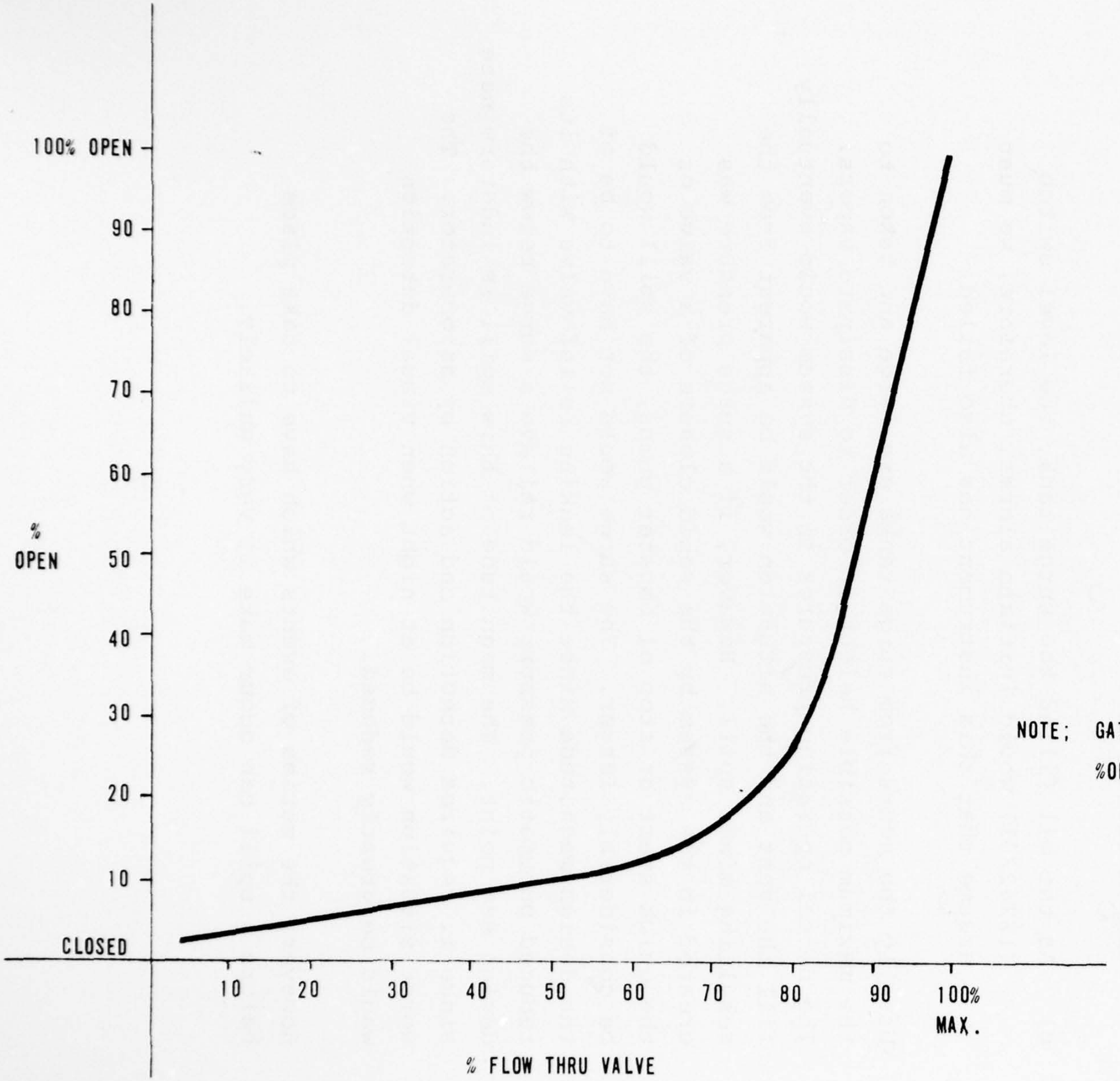
a) The relief valves are passing oil due to the failure of a PCV (Pressure Control Valve 12244/01) to maintain the correct pneumatic pressure.

b) Normally this would alarm in the control room so it has to be accompanied by the failure of a pressure switch (12243/02).

c) As the oil filled the surge tank, the level switch (12242/01) would initiate alarms, therefore, we must assume that this instrument has also failed.

Usually the vents from surge tanks are large and taken to the maximum possible height in order to dissipate vapors. The normal operating pressures in the system would eventually fill the vent and the situation would be apparent from the resulting minor spill. However, if a surge pressure was created in the system by the rapid closure of a valve or the quick start or stop of booster pumps, the spill would be considerably larger. The surge would not have to be of the design magnitude since the leaking relief valve with its reduced pneumatic pressure would relieve a surge below the design set point. The magnitude of this spill is indeterminate since it requires detection and action by an operator. The worst situation would be at night when visual detection would be greatly reduced.

However, the series of events which have to take place before a spill can occur make it very unlikely.



NOTE; GATE VALVE CHARACTERISTICS
%OPEN VS. FLOW RATE

FIGURE F-1 GATE VALVE CHARACTERISTICS SCENARIO F.2

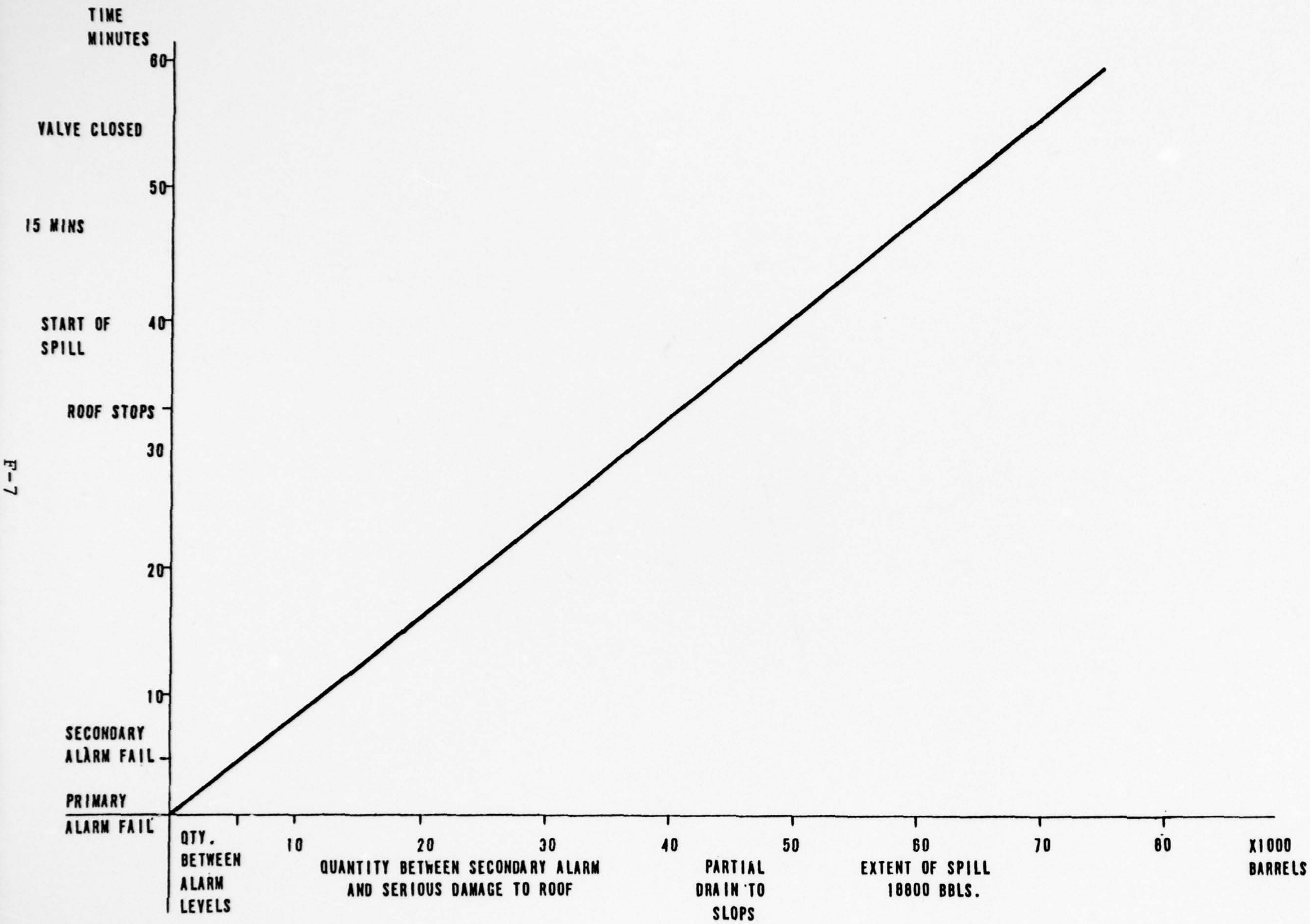


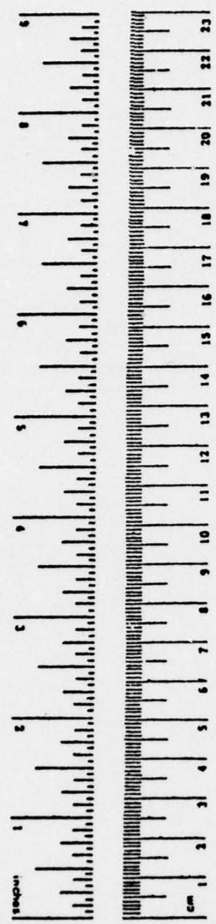
FIGURE F-2. SPILL MAGNITUDE SCENARIO F.2

*U.S. GOVERNMENT PRINTING OFFICE : 1978 0-726-748/1597

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F